THE SMILE

Environmental Life Cycle Assessment

SUMMARY

'The Smile' was made predominantly in tulipwood, one of the most abundant American hardwoods with forest volume of over 1000 million m^3, 7% of the total U.S. hardwood resource. Tulipwood is under-utilised from a sustainable forestry perspective, in the sense that creation of larger markets for this timber would reduce pressure on other less abundant commercial hardwood species and enhance returns from sustainable management of diverse semi-natural forests. The volume of tulipwood standing in U.S. hardwood forests expands by 19 million m^3 every year. It takes less than 5 minutes for the 270 cubic meters of tulipwood logs harvested to manufacture The Smile to be replaced by new growth in the U.S. forest.

The carbon footprint of The Smile was –(minus) 5.6 metric tonnes (MT) of CO_2 equivalent on delivery to the site in Chelsea. In other words, at this stage of the life cycle The Smile (including both the main structure and all the elements such as displays and handrails) was better than carbon neutral. Carbon emissions of 91.9 MT CO_2 eq. were offset by 25.8 MT CO_2 eq. due to burning of wood offcuts produced at the factories in Germany and Italy (which substituted for fossil fuel) and 71.6 MT CO_2 eq. of carbon stored in the wood in the finished design.

Although the quantity of non-wood materials in The Smile was small relative to wood, their contribution to total carbon emissions was more significant. Non-wood components, principally steel fixings with a small quantity of glues and coatings which together made up 7% of the total mass of The Smile, contributed 24.9 MT CO_2 eq. (27%) of carbon emissions.

Circumstances dictated that The Smile could not be moved to another location after the London Design Festival and the decision taken to dispose of the structure in the most efficient way possible - both from a cost and environmental perspective. The wood incorporated into The Smile was not contaminated with chemicals or mixed with other materials and could be readily incinerated in a modern waste disposal facility. This meant foregoing carbon storage benefits and additional emissions to transport the waste wood for incineration. However, these additional impacts were partially offset by the useful heat and electrical energy generated from the waste wood material which substituted for fossil fuels. The energy generated was 549 GJ, equivalent to total average consumption of one EU citizen over a four and half year period[1].

The carbon footprint of The Smile through all stages of the life cycle including final disposal was 38.7 MT CO_2 eq., about the same as emitted during 15 return flights between the UK and Australia[2]. This significant impact on a full cradle-to-grave basis is symptomatic of a one-off demonstration project which involved a lot of trial and error and was short-lived. As a demonstration, the environmental and technical information The Smile provides, and the message sent out about a new material – hardwood CLT, are perhaps more relevant than the immediate and more readily quantifiable environmental impacts at the time and place it was on display. The results highlight that delivery of hardwood CLT to the construction site can be carbon neutral and that there are significant environmental benefits to be derived from ensuring that, once installed, the material has a long lifetime in use. There are reasons to believe that this would be the case in commercial projects as hardwood CLT is designed for structural applications with a service life of several decades at least.

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1) Based on www.carbonfootprint.com calculator which estimates return economy flight between London Heathrow and Sydney has carbon footprint of 2.643 MT CO2 eq.

2) EU per capita primary energy consumption in 2014 was 124 GJ calculated from EC Joint Research Centre Report on Energy Consumption and Energy Efficiency Trends in the EU28 which estimated total EU primary energy consumption of 63000m GJ in 2014 and Eurostat estimate of EU population of 508m on 1 January 2015.

The Smile at the Rootstein Hopkins Parade Ground of the Chelsea College of Arts

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INTRODUCTION

'The Smile' was a collaboration of the American Hardwood Export Council, Alison Brooks Architects, Arup and the London Design Festival to design, engineer, and manufacture an innovative cross-laminated tulipwood structure for display in the Rootstein Hopkins Parade Ground of the Chelsea College of Arts from 17 September until 12 October 2016.
The Life Cycle Assessment (LCA) quantifies the environmental impacts of 'The Smile' covering all processes from extraction of wood and other raw materials, transport of these materials to processing location, all manufacturing steps, delivery of all components to the site at Chelsea, installation and subsequent dismantling and removal of all elements from the site, through to final disposal.
The Smile installation, including the main structure and additional elements such as displays and handrails, had a total mass of 48.9 Metric Tonnes (MT), comprising American tulipwood, German spruce, steel fixings, glues and coatings (Figure 1).
In any LCA there will be data gaps and various assumptions are made. The analysis errs on the side of caution and aims to over-estimate rather than to under-estimate environmental impact. The American tulipwood is assumed to have originated from the central point of tulipwood harvest in the U.S. (close to where the borders of Kentucky, Virginia and West Virginia meet). The logs were transported 120 km for sawing, then another 100 km for kilning, before being trucked 750 km to the port of Norfolk on the east coast. From there some of the tulipwood was shipped 6750 km to the port of Hamburg and trucked another 750 km to Züblin Timber in Aichach, Germany, where the main structure of The Smile was fabricated. Another batch of tulipwood was shipped 7900 km to the port of Genoa in Italy, trucked 300 km to Imola Legno in Italy for sorting and ripping, and then trucked 700 km to Aichach in Germany. A small volume was also sent by Imola Legno to the UK, via the port of Rochester, to be manufactured into smaller joinery elements contained in The Smile by AJ&B in Deptford, near London.
The spruce (which was combined with tulipwood to manufacture some of the CLT panels) was harvested, sawn and kilned in Germany and is assumed to have been transported 1000 km by truck for delivery to Züblin Timber. In the absence of detailed product-specific information, all other components (steel, glues, and coatings) are assumed to have originated from a European manufacturing location and to require transport of 1000 km by road, 500 km by train and 100 km by ship for delivery to Züblin.
Transport of The Smile main structure from Aichach to Chelsea included 1000 km by road and 100 km by ship.

FIGURE 1: COMPOSITION OF THE SMILE

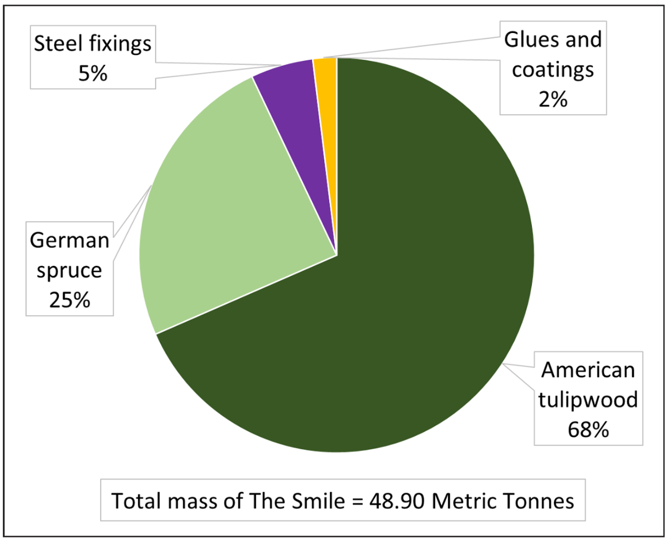

FIGURE 2: WOOD CONTENT & WASTE

	Unit	Tulipwood	Spruce	Total
Kiln dried sawn wood delivered to manufacturing sites in Germany, Italy & the UK				
Quantity	Cubic meters	135.7	43.5	179.2
	Metric tonnes (MT)	60.9	20.4	81.3
Replacement time (1)	Seconds	264.0	61.0	325.0
On leaving manufacturing sites in Germany, Italy and the UK				
Installed in 'The Smile'	Metric tonnes (MT)	33.5	12.0	45.4
Biogenic (stored) carbon (2)	MT CO_2 eq.	52.7	18.9	71.6
Incinerated	Metric tonnes (MT)	27.5	8.5	35.9
At end of The Smile's life				
Incinerated	Metric tonnes (MT)	31.8	11.4	43.2

1) Time in seconds for new growth in U.S. hardwood forest to replace wood harvested to supply the project. Harvested log volume is assumed to be double the volume of delivered boards. Forest growth data is from the USDA Forest Inventory and Analysis (FIA) Program.
2) Biogenic carbon is the carbon stored in wood material during growth and is treated as a negative emission. Due to difficulties of tracing carbon flows at every stage of the life cycle, carbon storage is calculated directly from the mass of the delivered hardwood assuming that 46% of dry mass consists of carbon (where 1 kg of carbon is equivalent to 3.67 kg of carbon dioxide).

KEY FACTORS INFLUENCING ENVIRONMENTAL IMPACT

Three factors are important to understand the environmental implications of The Smile. The first is that 93% of the structure was composed of wood, all known to derive from renewable sources. The majority was American tulipwood, a species which is under-utilised from a sustainable forestry perspective, in the sense that creation of larger markets for this timber would reduce pressure on other less abundant commercial hardwood species and enhance returns from sustainable management of diverse semi-natural forests. Far from damaging the natural environment, increased use of American tulipwood has potential to reduce carbon emissions by substituting for other more energy-intensive materials and by expanding the pool of carbon contained in buildings and furniture and thereby supplementing the growing carbon stock in the forest.
The second factor is that The Smile was a one-off demonstration of the technical and environmental potential of a new construction product - hardwood CLT. The potential The Smile shows, and the message it sends out, are perhaps more relevant than the immediate - and more readily quantifiable - environmental impacts of The Smile at the time and place it was on display. Furthermore, the immediate environmental impact of a demonstration project will tend to be high relative to a more highly evolved commercial operation. A feature of demonstration projects is that they involve experimentation and trial and error and often rely, due to lack of local capacity to undertake the required cutting-edge work, on manufacturers at some distance from the project site. In this case, the manufacturer was based in Germany and reliant mainly on wood donated by AHEC members not

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necessarily of the optimum grade for the task required. This contributed to a relatively high quantity of wood waste and a lot of transport even after the wood reached the EU. If the project were to encourage development of tulipwood CLT as a commercial product, manufacturers would purchase tightly specified material and develop specific tooling and processes for more efficient fabrication and distribution.

The third factor is that, due to circumstances outside the organisers control, the Smile was short-lived. The original intent was to maximise the potential of The Smile as a demonstration project, and its environmental benefit as a long-term store of carbon (the wooden structure contained 71.6 MT CO_2 Eq of biogenic carbon), by moving it to another more permanent location after the London Design Festival. However, the costs of dismantling and reconstructing the whole structure in another location proved too much and the decision was taken to dispose of the structure in the most efficient way possible - both from a cost and environmental perspective. A specialist disposal contractor - Syd Bishop & Sons (Demolition) Ltd – was commissioned to break The Smile into small components and particulates on-site, thereby allowing efficient transport out of central London. Because the wood incorporated into The Smile was not contaminated with chemicals or mixed with other materials, it could be readily incinerated in a modern waste disposal facility, thereby generating heat and electrical energy and offsetting use of fossil fuels.

The wood material from The Smile was incinerated not in the UK, but in Germany. This meant more transport which reduced the environmental benefit. However, at present Germany has a better developed infra-structure, and offers better prices, for disposal of wood waste than the UK. This reflects Germany's commitment to the Erneuerbare Energien Gesetz (EEG) which sets a national target for renewables to contribute 40% to 45% of energy consumed in Germany by 2025 and 55% to 60% by 2035 and which provides significant subsidies in support of this aim. As Germany is also committed to phasing out all nuclear energy by 2022 (nuclear energy contributed a quarter of German electricity before 2011), there has been a strong focus on biomass energy production in Germany which is less variable, and often more cost-effective, than wind and solar.

SCOPE OF THE LCA

From an LCA perspective, early disposal of the Smile facilitated preparation of a genuine "cradle-to-grave" assessment since the actual fate of materials in The Smile could be tracked all the way through to final disposal. However, it also

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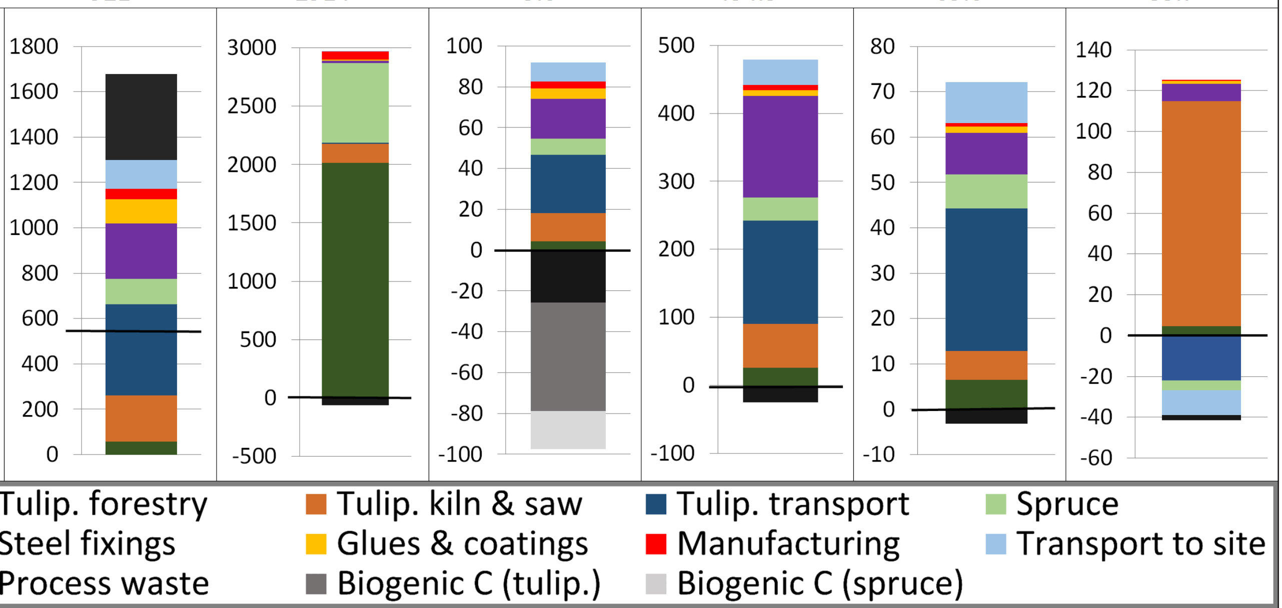
FIGURE 3: CRADLE TO SITE ENVIRONMENTAL IMPACT OF THE SMILE

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	921	2914	-5.6	454.5	69.0	83.7

Data by process steps



Impact Category	Unit	American hardwood			Spruce	Steel fixings	Glues & coatings	Manu-facturing	Transport to site	Process waste	Stored carbon		Total
		Forestry	Proc-essing	Transport							Tulip-wood	Spruce	
PED (non-renewable)	GJ	57.8	203.8	402.4	109.8	246.1	106.0	46.4	126.8	-377.8	n/a	n/a	921.3
PED (renewable)	GJ	2015.9	161.4	9.5	683.3	20.7	7.5	70.2	7.2	-61.2	n/a	n/a	2914.4
Global Warming Potential	MT CO2-Equiv.	4.3	14.0	28.5	7.7	19.6	5.3	3.2	9.3	-25.8	-53.1	-18.6	-5.6
Acidification Potential	kg SO2-Equiv.	25.7	65.0	151.9	33.3	149.7	8.2	7.7	37.4	-24.5	n/a	n/a	454.5
Eutrophication Potential	kg Phosphate-Eq.	6.4	6.4	31.4	7.5	9.2	1.4	0.8	9.1	-3.1	n/a	n/a	69.0
POCP	kg Ethene-Equiv.	4.6	110.1	-22.0	-4.7	8.7	1.2	0.5	-12.2	-2.6	n/a	n/a	83.7

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meant the project departed even further from the reality of a real world CLT application. If developed for commercial use, hardwood CLT is likely to be used structurally and to have a service life of several decades at least.

To partially overcome this last short-coming, and provide greater insights into the likely environmental impact of hardwood CLT in more typical applications, two sets of LCA results are provided for The Smile:

- **Cradle-to-site**: Figure 3 summarises environmental impact to the point at which all the hardwood CLT and other components is delivered to the site in Chelsea. This provides an insight into the immediate environmental impact of supplying all the materials required and to fabricate and deliver a large structure in hardwood CLT. It also highlights the potential benefits in terms of carbon storage of maintaining such a structure over the long term.
- **Cradle-to-grave**: Figure 4 extends the LCA to include the impacts of disposing of the structure in the way and at the time dictated by circumstances. Disposal involved additional energy to break-up The Smile and transport to Germany for incineration. It also meant forgoing carbon storage benefits. These impacts were partially offset by the energy generated from the waste wood material.

The LCA includes quantitative assessment against six environmental impact categories particularly relevant to wood products and for which there is broad scientific agreement on methodology (Figure 5). There is also qualitative assessment of impact on forest condition drawing on the LCA of U.S. sawn hardwood prepared by PE International (now Thinkstep) in July 2012 and latest data from the U.S. Forest Service Forest Inventory and Analysis (FIA) Program.

GLOBAL WARMING POTENTIAL (GWP)

Cradle-to-site

The GWP or "carbon footprint" of The Smile was –(minus) 5.6 metric tonnes (MT) of CO_2 equivalent on delivery to the site in Chelsea. In other words, at this stage of the life cycle The Smile (including both the main structure and all the elements such as displays and handrails) was better than carbon neutral. Carbon emissions of 91.9 MT CO_2 eq. were offset by 25.8 MT CO_2 eq. due to burning of wood offcuts produced at the factories in Germany and Italy (which substituted for fossil fuel) and 71.6 MT CO_2 eq. of carbon stored in the wood in the finished design.

Although the quantity of non-wood materials in The Smile was small relative to wood, their contribution to total carbon

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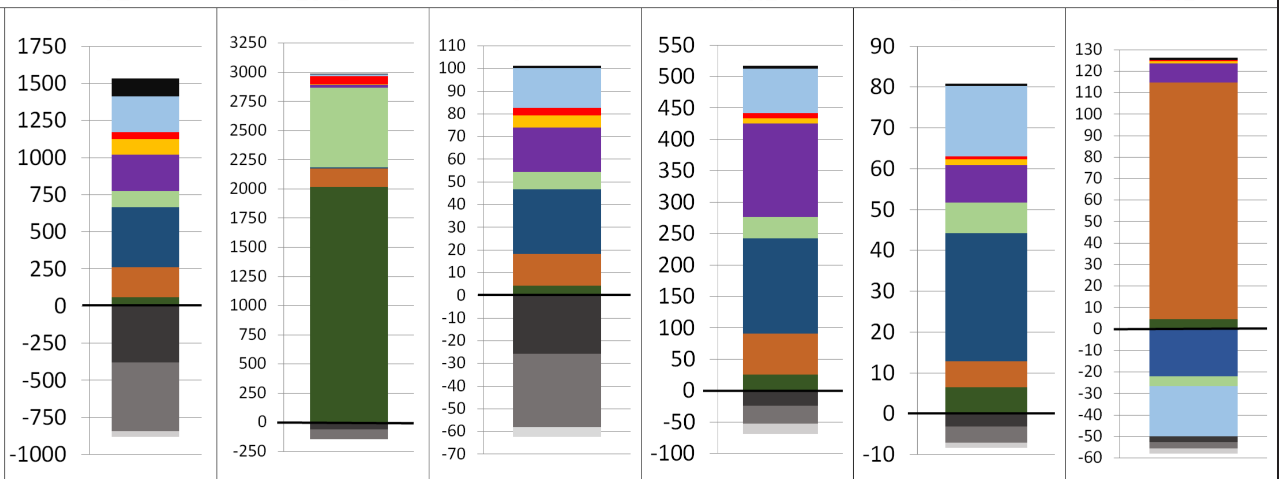
FIGURE 4: CRADLE TO GRAVE ENVIRONMENTAL IMPACT OF THE SMILE

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	MT CO2-Equiv.	kg SO2-Equiv.	kg Phosphate-Equiv.	kg Ethene-Equiv.
Total	652	2842	38.7	448.2	72.4	68.1

Data by process steps



Key
- Tulip. forestry
- Tulip. kiln & saw
- Tulip. transport
- Spruce
- Steel fixings
- Glues & coatings
- Manufacturing
- Transport to & from site
- On-site
- Process wood energy
- EoL wood energy
- EoL recycled steel

Impact Category	Unit	American hardwood			Spruce	Steel fixings	Glues & coatings	Manu-facturing	Transport to & from site	On-site	Process wood energy	EoL wood energy	EoL recycled steel	Total
		Forestry	Proc-essing	Transport										
PED (non-renewable)	GJ	57.8	203.8	402.4	109.8	246.1	106.0	46.4	240.8	120.8	-377.8	-465.9	-38.3	651.9
PED (renewable)	GJ	2015.9	161.4	9.5	683.3	20.7	7.5	70.2	13.6	2.5	-61.2	-82.9	2.1	2842.5
Global Warming Potential	MT CO2-Equiv.	4.3	14.0	28.5	7.7	19.6	5.3	3.2	17.7	0.9	-25.8	-32.4	-4.3	38.7
Acidification Potential	kg SO2-Equiv.	25.7	65.0	151.9	33.3	149.7	8.2	7.7	71.1	4.5	-24.5	-28.0	-16.4	448.2
Eutrophication Potential	kg Phosphate-Eq.	6.4	6.4	31.4	7.5	9.2	1.4	0.8	17.2	0.5	-3.1	-4.0	-1.3	72.4
POCP	kg Ethene-Equiv.	4.6	110.1	-22.0	-4.7	8.7	1.2	0.5	-23.2	0.9	-2.6	-3.2	-2.4	68.1

FIGURE 5: ENVIRONMENTAL IMPACT CATEGORIES

1 PRIMARY ENERGY DEMAND (NON-RENEWABLE RESOURCES)

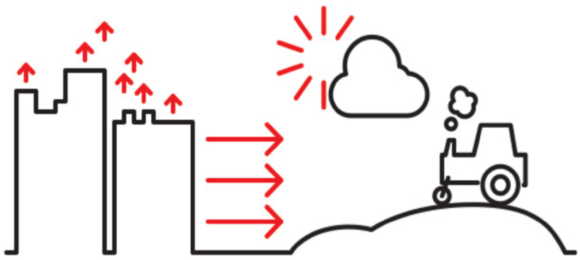
This is a measure of the total demand of primary energy that comes from non-renewable resources, such as oil and natural gas. Measured in gigajoules (GJ), the primary energy demand takes into account the conversion efficiencies from the primary energy to, for example, electricity. The generation of carbon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

2 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

3 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.

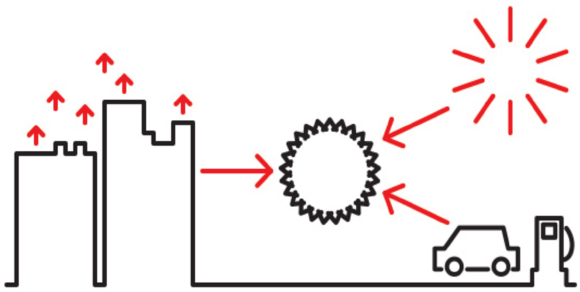


4 ACIDIFICATION POTENTIAL (AP)

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.

5 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.



6 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.

LAND USE CHANGE, RENEWABILITY AND BIODIVERSITY

The LCA of U.S. hardwood undertaken by PE International concludes that 'in the system under investigation the main material – wood – comes from naturally re-grown forests. The harvested areas had undergone several iterations of harvesting and re-growth. After harvesting, the land is returned to forest so there is no direct land use change to account for in the timeline of few hundred years.'

On biodiversity impacts, PE International concludes: 'conversion of any other commercial land into the hardwood forest would most probably have a positive impact on the land quality including biodiversity and associated ecosystem services.'

U.S. Forest Service FIA program data shows that the total area of hardwood and mixed hardwood-softwood forest types in the U.S. increased from 99 million hectares in 1953 to 111 million hectares in 2012. Area increased consistently throughout the 60-year period and continued at a rate of 401,000 hectares per year between 2007 and 2012. Between 2007 and 2012, the volume of hardwood standing in the U.S. increased at a rate of 124 million m^3 a year.

FIA data also confirms that hardwood harvesting is not threatening biodiversity by replacing older more diverse forests with plantations. In 2012, natural forests accounted for 97% of the area of hardwood and mixed hardwood-softwood forest types in the U.S. and only 3% were plantations. U.S. hardwood forests are aging and more trees are being allowed to grow to size before being harvested. The volume of hardwood trees with diameters 48 cm or greater increased nearly four-fold from 0.73 billion m^3 in 1953 to 2.7 billion m^3 in 2012.

It takes less than 5 minutes for the tulipwood needed to manufacture The Smile to be replaced by new growth in the U.S. forest

'The Smile' is made predominantly in tulipwood, one of the most abundant American hardwoods with forest volume of over 1000 million m^3, 7% of the total U.S. hardwood resource. Every year, the volume of tulipwood in U.S. forests grows on average by 32 million m^3, of which only 13 million m^3 is harvested. This means the volume standing in U.S. hardwood forests expands by 19 million m^3 every year. It takes less than 5 minutes for the 270 m^3 of tulipwood logs harvested to manufacture The Smile to be replaced by new growth in the U.S. forest.

Like most U.S. hardwoods, tulipwood is typically harvested using the selective single tree method to create or maintain an uneven-aged forest stand. This avoids the potentially negative visual impacts associated with clear-cutting and helps to prevent soil erosion and maintain bio-diversity. The first picture (right above) derives from Rockingham County in Virginia and shows a tulipwood stand that has been harvested twice since the late 1970s and which is now ready (in 2010 when the picture was taken) for a third cut. The second picture (right below), also from Virginia shows another tulipwood stand five months after harvesting.

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emissions was more significant. Non-wood components, principally steel fixings with a small quantity of glues and coatings which together made up 7% of the total mass of The Smile, contributed 24.9 MT CO_2 eq. (27%) of carbon emissions.

The environmental impact of the steel would be greater if it were derived from manufacturers located further from the UK, or in countries with an energy mix less dependent on renewable energy than Germany, or where there were less efficient transport networks for supply of both raw materials and finished product.

In this respect, it is worth noting that Asian suppliers, particularly in China, are increasing their share of the UK steel market and now account for 16% of UK steel imports and about 8% of UK steel consumption. This has potentially significant implications for the environmental impact of the steel supplied, not only due to transport but also relatively high dependence on coal and other fossil fuels in the energy mix of many Asian countries.

Cradle-to-grave

The carbon footprint of The Smile through to final disposal was 38.7 MT CO_2 eq. That's about the same as emitted on average by four UK citizens each year and equivalent to around 15 return flights between the UK and Australia.

Only 0.9 MT CO_2 eq. was emitted during all the on-site work to install and then dismantle The Smile at the London Design Festival, less than 1% of all emissions associated with the project.

Transport of the waste material from the site for disposal at the end of the London Design Festival added 8.4 MT CO_2 eq., relatively high due to the wood waste being shipped to Germany for incineration. Incineration at end of The Smile's life provided an additional carbon offset of 32.4 MT CO_2 eq. as it substituted for use of fossil fuels in Germany. However, this offset was insufficient to fully compensate for the loss of 71.6 MT CO_2 eq. of carbon storage in The Smile.

Local incineration would have been more beneficial from a carbon perspective due to lower emissions during transport and a larger offset because fossil fuel dependence is currently higher in the UK than in Germany (in 2014, fossil fuels accounted for 85% of energy production in the UK compared to 74% in Germany).

ACIDIFICATION POTENTIAL

Cradle-to-site

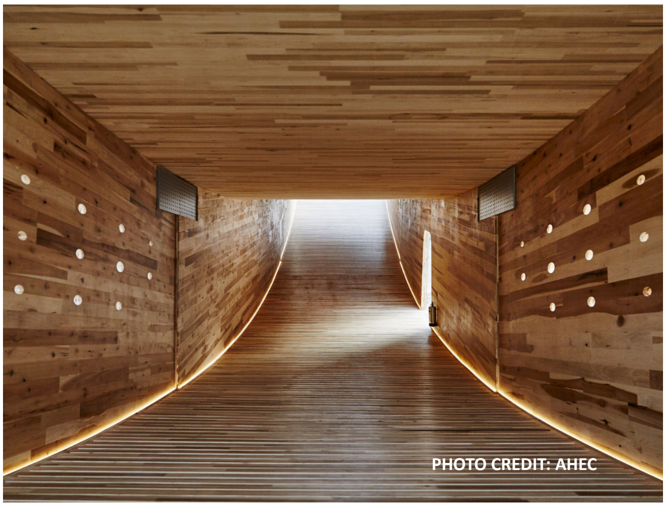
The acidification potential of The Smile was 454 kg of SO_2 (sulphur dioxide) equivalent on delivery to the site in Chelsea. Acidification is caused mainly by the burning of fossil fuels and the scale of impact is directly related to their sulphur content.

33% of the acidification potential was due to emissions during shipping of hardwoods from the U.S. to Europe and is heavily influenced by the assumptions made about sulphur content of marine fuels. The LCA assumes an average sulphur content of 2.7% for the fuel used on the ships transporting the wood from the U.S. This is almost certainly an over-estimate. It exceeds the global average figure of 2.4% for 2010 provided by the International Maritime Organisation (IMO), an average already skewed by relatively high figures for shipping in the Middle East and Asia.

In addition, progress is being made to further reduce the sulphur content of marine fuels through the International Convention for the Prevention of Pollution from Ships (MARPOL). Since 1 January 2015, ships trading in designated emission control areas under MARPOL have been required to use on board fuel oil with a sulphur content of no more than 0.1% (a limit of 1.0% was in effect until 31 December 2014). These stringent requirements now apply to all ships operating within 200 nautical miles of the coast of North America and in the North Sea, Baltic Sea and English Channel. In November 2016, the IMO agreed that a 0.5% global limit for sulphur content in ship fuel oil will apply from 2020.

32% of the acidification potential was due to steel fixings, a high proportion when it is considered that the steel contributed only 5% of the mass of The Smile. The contribution of the steel would have been even higher if sourced from a country other than Germany with higher dependence on coal and other fossil fuels for energy supply or requiring longer delivery distances.

14% of the acidification potential of The Smile was due to emissions during hardwood processing in the United States. A significant proportion is due to use of grid electricity, mainly to power fans during the lengthy kiln drying cycles. Two thirds of energy for electricity generation in the U.S. derives from fossil fuel, half of which is coal which has a higher sulphur content than natural gas. Some acidification potential is also due to biomass combustion to provide the thermal energy for kiln drying.



Cradle-to-grave

The acidification potential of The Smile through to final disposal was 448 kg of SO2 (sulphur dioxide) equivalent. On-site work in Chelsea added 5 kg SO_2 eq. to the acidification potential, and transport from the site for disposal a further 34 kg SO_2 eq. However, by substituting for fossil fuel, generation of energy from the wood waste at end of life reduced the acidification potential by 28 kg SO_2 eq. Recycling the 5 kg of steel provided an additional offset of 16 kg SO_2 eq.

PHOTOCHEMICAL OZONE CREATION POTENTIAL (POCP)

Cradle-to-site

The Smile had a POCP of 84 kg of ethene equivalent on delivery to the site in Chelsea. This comprises 125 kg ethene eq. of emissions with an offset of 41 kg ethene eq. mainly attributed to the transport stages.

The offset due to transport is explained by emissions of nitric oxide (NO) when transport fuels are burnt which can then react with ozone (O_3) to form nitrogen dioxide (NO_2) and oxygen (O_2) under certain conditions. This has a negative effect on POCP since it reduces the concentration of ozone close to the ground. This offset, while currently allowed under official LCA rules, is being debated in the LCA science community as it sends out a questionable signal about the environmental "benefits" of transport.

Nearly all the POCP was attributed to the hardwood processing stage in the U.S. and is due to emissions of terpenes, volatile organic compounds (VOCs) released from wood resins. Terpenes are released naturally as trees grow, but processes in which wood is heated (such as a kiln drying) result in more significant emissions. In practice, there is substantial variation in the level of VOC emissions between species and they also depend on drying times and on other factors such as the mix of heartwood and sapwood.

Most U.S. hardwood processing happens in rural areas with the implication that terpene emissions are less likely to contribute to urban smog. Terpenes have a short atmospheric lifespan and the highest photo-oxidant concentrations are expected within five hours after the emission takes place and within 50 km distance. The environmental impact of terpenes also varies widely depending on the local presence of other pollutants, notably nitrogen oxides. For the public, the smell around wood-processing units is likely to be the most noticeable environmental effect.

Nevertheless, the photo-oxidants created due to terpene emissions can cause forest and crop damage, and they are harmful to humans as they cause irritation in the respiratory tract and in sensitive parts of the lungs. This finding highlights the need for more work to understand the specific impacts of terpene emissions within the context of U.S. hardwood kilning facilities and the actions required to mitigate these impacts.

Cradle-to-grave

POCP of The Smile through to final disposal was 68 kg of ethene equivalent. This is significantly lower than POCP at point of delivery to Chelsea due to offsets created by energy production from waste wood at end of life and by recycling of steel (both of which reduce demand for fossil fuels in other industrial processes). There is also the (more controversial) offset attributed to transport from the site.

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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.

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 WAS 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 a wide-ranging 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 at Züblin Timber in Germany and Imola Legno in Italy and following disposal from Syd Bishop & Sons (Demolition) Ltd and Pinden Ltd (Waste Management). It is also combined with Thinkstep's existing life-cycle inventory database which covers an expanding range of non-wood materials and products.

a. The Thinkstep LCA study of U.S. sawn hardwood is available at http://www.americanhardwood.org/fileadmin/docs/sustainability/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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EUTROPHICATION POTENTIAL

Cradle-to-site

The eutrophication potential of The Smile on delivery to Chelsea was 69 kg of phosphate equivalent – about the same as that caused each year by conventional farming of three hectares of land for wheat in the UK. Perhaps surprisingly, hardly any of the eutrophication associated with The Smile is linked to the growth of U.S. hardwood. Fertilisers are very rarely needed to encourage growth of American hardwoods since they thrive under natural conditions. Instead, nearly all eutrophication potential of The Smile is due to nitrate emissions during burning of fuels for transport and processing of materials.

Cradle-to-grave

The eutrophication potential through to final disposal was 72 kg of phosphate equivalent. This is only slightly more than the cradle-to-site impact as the eutrophication potential to transport waste material for disposal at the end of the project was offset by energy production from waste wood at end of life and by recycling of steel (both of which reduce demand for fossil fuels in other industrial processes).

PRIMARY ENERGY DEMAND

Cradle-to-site

1299 GJ of non-renewable (fossil fuel) energy was used during all life cycle stages to deliver The Smile to Chelsea, 60% to supply the wood, 27% to supply other materials (mainly steel), 4% during manufacturing in Germany and Italy, and 10% to transport the structure from Germany to the UK. Incineration of process waste at various stages offset demand for non-renewable energy by 378 GJ.

2975 GJ of renewable energy was used during all life cycle stages to deliver The Smile to Chelsea. Burning of process waste offset demand for renewable energy by 61 GJ.

68% of renewable energy input is attributed to the forestry stage in the U.S. and 23% to supply of spruce. However, this is not energy used during forestry operations but consists of solar energy absorbed by the tree during growth and converted into chemical energy within the wood itself. It is effectively equivalent to the energy that would be released if the wood were burnt immediately after harvest and is recorded in LCA of wood products to ensure full accounting of energy streams.

Much of the remaining renewable energy is used during the wood processing stages and is indicative of the high dependence on biomass to produce thermal energy during kiln drying. At least 90% of all thermal energy used for kiln drying in the U.S. hardwood sector is derived from biomass.

Cradle-to-grave

An additional input of 123 GJ of primary energy was required on-site to install and remove The Smile in Chelsea, together with 120 GJ to transport the waste, mainly wood fibre destined for incineration in Germany. This energy was almost exclusively from fossil fuel, with only a small input of renewables. However, incineration of the wood contained in The Smile generated 549 GJ of energy, offsetting demand for 466 GJ of fossil fuel energy and 83 GJ of renewable energy. The energy generated was equivalent to the total consumed on average by one EU citizen over a four and half year period.

THE SMILE

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