TELLING THE WHOLE STORY: THE ENVIRONMENTAL LIFE CYCLE OF AMERICAN HARDWOODS

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SUMMARY

What is LCA?

All products have an impact on the environment and this impact can occur at any time during the manufacture, usage or at end of life. All these stages are collectively called a life cycle. Products have impacts from material extraction and transport; processing, manufacture, distribution and installation; maintenance and refurbishment; to eventual end of life and disposal. The measurement of this impact is called Life Cycle Assessment (LCA).

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 life cycle. LCA quantifies environmental effects against a range of impacts such as on air quality, water usage and water quality, toxicity to human life and to ecosystem functioning, global warming, as well as resource use. LCA may also provide qualitative assessment of other environmental impacts, such as on biodiversity and land-use, that are less easy to quantify.

LCA helps to rectify common misconceptions

A key strength of LCA is that it rectifies misconceptions and highlights the critical trade-offs when seeking to minimise environmental impacts. For example, a common assumption is that carbon emissions associated with transport are of overwhelming significance to environmental impact and that local materials are therefore always better for the environment.

However, LCA reveals that for many products, including American hardwoods, the efficiency of production and mix of energy used at the manufacturing location are often much more significant. Environmental impacts can therefore be reduced by preferring the material from the most efficient processing site even if that is some distance from the point of consumption.

WHY LCA?

AHEC recognises LCA as the most effective tool to demonstrate sustainability in material specification and green building design because:

- **LCA is science-based:** LCA is an objective non-biased systematic process which identifies and measures material and energy flows through the entire life cycle of a product.
- **LCA applies to all material sectors** and allows objective comparisons to be made of their true environmental impact.
- **LCA is comprehensive with respect to materials, processes and impacts**, thereby allowing designers and manufacturers to identify the processes and materials which cause greatest environmental impact and the most efficient ways to reduce those impacts. It helps ensure that efforts to reduce one impact do not result in environmental degradation elsewhere.
- **LCA is standardised:** international standards have been developed to ensure worldwide consistency in the conduct, review, presentation and use of LCA.
- **LCA is increasingly accessible:** while LCA requires the collation and systematic analysis of vast quantities of data, comprehensive global databases and computer software are becoming more readily available to facilitate use of LCA even by smaller operators.
- **Demand for LCA is rising:** regulators and large corporate and public buyers are increasingly recognising the value of an LCA based approach to reduce environmental impacts and are demanding LCA data from material and product suppliers.

INTERNATIONAL LCA STANDARDS

Standards have been developed by the International Organisation for Standardization (ISO) to ensure international consistency in the conduct, review, presentation and use of life cycle assessment. The ISO14000 series of standards includes the following:

- ISO 14040 specifies the general framework and principles for LCA studies but does not describe the life cycle assessment technique in detail.
- ISO 14044 specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, and relationship between the LCA phases.
- ISO14048 provides requirements and a consistent structure for a data documentation format to be used for exchange of LCA and Life Cycle Inventory (LCI) data.
- ISO 14047 and ISO14049 provide examples to illustrate current LCA practice according to ISO 14044.
- ISO 14071 provides additional requirements and guidelines for conducting a critical review of any type of LCA study and the competencies required for the review.
- ISO 14025 establishes principles and specifies procedures for developing environmental declaration programmes and so-called “Type III” environmental product declarations or EPDs. It requires the use of the ISO 14040 series of standards in the development and issue of EPDs.

THE LCA PROCESS

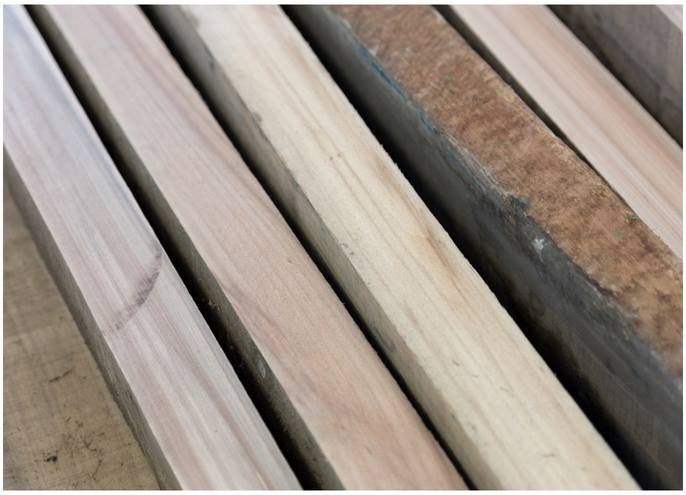
There are five major steps required to carry out an LCA:

- **Goal and scope:** The first step is to consider the goal and scope of the study including an explanation of the context of the study, its boundaries and methodology and how and to whom the results are to be communicated. Information must be provided on: the “functional unit" to be assessed (for example "one cubic meter of American sawn hardwood",or "set of four chairs"); the sources of data; the assumptions to be made during the study; the range of environmental indicators to be assessed and justified; and the life cycle phases to be included.

- **Data collection:** The next step is to gather "life cycle inventory" data for all the processes involved within the scope of the study. This will cover the input materials and energy used and the waste and emissions produced at each stage.

- **Modelling:** The next step is to build a model of the processes within the scope of the study, and to link this to existing LCA data sets for the upstream and downstream processes so that a complete system model is produced.

- **Interpretation:** The final stage is analysis using the results of the modelling in the context of the goal and scope of the study.



- **Critical review:** If the study is to make public comparison then a critical review to ISO 14044 must be provided. The studies of U.S. hardwood lumber and veneer undertaken for AHEC by thinkstep were subject to critical review in line with this standard.

LIFE CYCLE MODELLING

Life cycle modelling, a critical step in the LCA process, is typically carried out using computer software which includes information for materials, energy and waste. For the LCA practitioner, modelling involves linking together, in a structured way, life cycle inventory data on all material and energy flows within the boundaries of the product system under consideration. All modelling work for LCA projects undertaken by AHEC to date has been carried out using thinkstep GaBi software. Other options include SimaPro and openLCA.
Using the software tool, the LCA practitioner enters the primary life cycle inventory (LCI) data collected during field studies. This data will include, for each functional unit at each process

stage, information such as the tonnage and type of material used or ending up as waste and diverted for co-products, incinerated or sent to landfill; the amount and type of energy consumed (such as electricity from the grid or solar panels, heating from natural gas or wood chips etc.); and the quantity and type of chemicals and particulates emitted to the air or water. Depending on the scope of the study, there may also be data showing how much of each functional unit ends up in landfill, or is recycled or burnt at the end of life.

The LCA software tool is used to link this primary LCI data collected in the field with existing LCA data sets for the upstream and downstream processes. In the thinkstep studies of U.S. hardwood lumber and veneer, upstream processes modelled using existing Gabi data sets included the supply of grid electricity in the U.S. and the transport of logs, green lumber

and other materials by truck, rail and container ship. Downstream processes modelled in this way included disposal and incineration of waste wood and other materials.
Once the model is built, the software takes care of the technical calculations required to convert LCI data into environmental impact data. This involves two steps which are built into the software with very little additional input required by the LCA practitioner:

- **Classification:** all substances are sorted into classes according to the effect they have on the environment. For example, substances that contribute to more than one environmental impact (such as nitrous oxides - NOx - that contribute to the greenhouse effect, ozone layer depletion, toxicity, acidification and eutrophication) are entered into all relevant impact classes.

- **Characterization:** the substances are aggregated within each class to produce an "effect score". Some substances may have a more intense effect than others – for example 1 kg of methane has around 30 times the global warming potential of 1 kg of carbon dioxide over a 100-year period. Therefore, it is not sufficient just to add up the quantities of substances involved and weighting factors need to be applied at this stage.

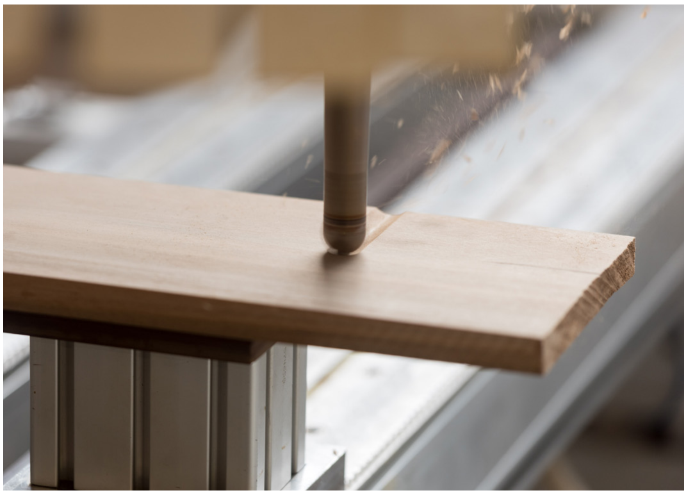
ENVIRONMENTAL IMPACT NUMBERS

The output from the LCA is a series of numbers which quantify total impact in each environmental category for the material or product being assessed. These numbers may be made available in the form of Environmental Product Declarations (EPDs) or as part of a distributed database (like GaBi) to manufacturers or designers interested in the environmental impact of their own products or designs that incorporate the assessed product. A software tool like GaBi or SimaPro is capable of generating numbers on a very large range of environmental impact categories, although usually the focus is on a limited number of categories required in specific standards for EPDs or for which there is particular concern amongst buyers or policy makers, such as global warming potential (often referred to as carbon footprint).
For information purposes, U.S. hardwood exporters can provide a core selection of environmental impact numbers derived from the thinkstep studies of U.S. hardwood using the American Hardwood Environmental Profile (AHEP) issued with the standard paperwork accompanying individual export consignments of U.S. hardwood.

Environmental impact numbers for an expanding range of materials and products are also being introduced as a component of Computer Aided Design (CAD) and Building Information System (BIM) software to allow assessment of environmental effects to be directly integrated into the design process.

KEY CONSIDERATIONS IN LCA

To be meaningful, LCA studies must compare like-with-like. Comparing the energy used to produce one tonne of wood with the energy to produce an equivalent mass of steel is of little relevance if three times as much wood is required to perform the same function.



Therefore the LCA must compare equivalent "functional units". For example, in the case of external cladding, the functional unit may be one square meter of wall that satisfies building regulations.

Because environmental implications vary from location to location, LCA models must incorporate relevant local conditions. For instance, electricity is used to varying degrees in the manufacture of most materials but there could be a significant difference in the environmental effects of electricity produced from coal versus electricity produced from solar or wind power.

The durability of products in use is another key factor in LCA. The environmental impact of a product that needs to be replaced three times during the lifetime of a building is effectively three times that of an equivalent product that needs to be replaced.

DESCRIPTION OF IMPACT CATEGORIES

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 CO_2, methane and water vapour) which influence the energy balance of the atmosphere leading to increased average temperatures.

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.

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 (SO_2) and nitrogen oxides (NOX). Expressed in Moles of H^+ equivalent or kg of sulphur dioxide equivalent.

Freshwater Eutrophication Potential: Nutrient enrichment of freshwater 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 the water. Expressed in kg of phosphate equivalent.

Marine Eutrophication Potential: Nutrient enrichment of marine waters 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 the water. Expressed in kg of nitrogen 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 Non-Methane Volatile Organic Compound (NMVOC) or kg ethene equivalent.

Abiotic Depletion Potential: Measures depletion of non-renewable mineral resources. Compiled from the ratios of annual production to size of remaining reserves for all minerals consumed. Expressed in relation to the ratio for the mineral Antimony (SB).

Ozone Layer Depletion: Measures depletion of ozone in the statosphere (which acts as a protective layer against ultraviolet radiation harmful to life) due to emission of CFCs and tetracholoromethane gases, among others. Usually expressed in kg of CFC-11 equivalent.

LIFE CYCLE INTERPRETATION

Having access to the numbers on individual environmental impacts is only the starting point for the next and most critical stage of the LCA process – that of interpretation. Unfortunately, this is usually not as simple as just stating that material A is better than material B, or product C is better than product D. Interpretation requires careful consideration of the relevance and importance of each impact category and of the context in which the materials or products are being used.

To aid interpretation, it is usually necessary to undertake a sensitivity analysis to identify which materials and processes contribute most to environmental impacts. This in turn can be used to identify the best strategies to reduce impacts. LCA modelling tools like GaBi and Simapro have in-built procedures for “parameterisation” which allow LCA practitioners to readily adjust specific variables and assess the effect on environmental impact. For example, in preparing their LCA report on U.S. hardwood lumber, thinkstep ran the GaBi model numerous times adjusting a wide range of parameters including lumber thickness (which impacts on drying time), transport distance and mode and types and sources of energy at various process stages. Another aid to interpretation is a process called “normalisation” which provides a better understanding of the relative size of an environmental effect. Each effect calculated for the life cycle of a product may be benchmarked against the known total effect for this class. For example, the “Eco-indicator” normalisation method compares effects with those caused on average by a single European during a year. A software tool like GaBi or SimaPro can be used to automatically normalise environmental effect scores using a range of methods.

ENVIRONMENTAL PRODUCT DECLARATIONS IN CONSTRUCTION

The quest to reduce the impact of rapidly rising global consumption on the environment has meant that demand for information on the impact of materials and production processes has increased dramatically.

This is particularly true of the construction sector which, according to UN Environment Program data, already accounts for around a third of global greenhouse gas emissions and a third of energy and materials consumed worldwide. Much attention is being given to new ways of designing and constructing buildings to reduce their environmental impact. While the focus has been on energy efficiency and capturing renewable energy, there is a growing awareness that the embodied impacts of construction products and especially embodied carbon will become increasingly important.

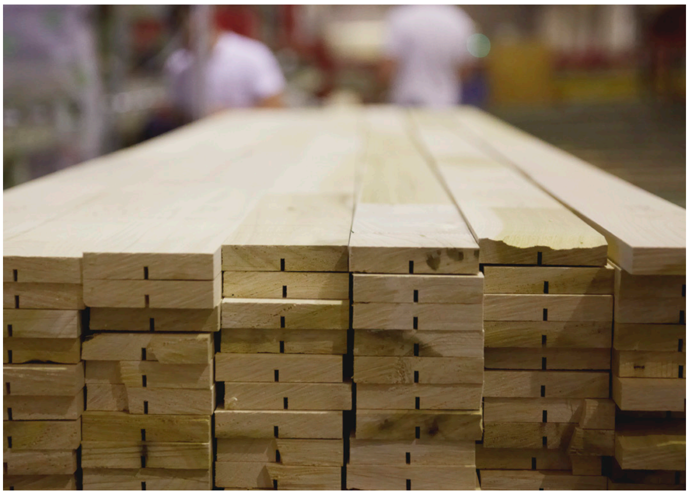
LCA-based Environmental Product Declarations (EPDs) are becoming the preferred tool for provision of environmental data in the construction sector. In ISO terminology, EPDs are defined in ISO 14025 as Type III labels that disclose life cycle environmental performance of products. They are not ‘green’ certificates or claims of environmental superiority (which are Type I labels). EPDs are more like nutrition labels which disclose data on nutritional performance in a structured way, without including judgements on health effects.

EPDs can be prepared by industry associations for generic products (for example “U.S. hardwood lumber”) or by companies for specific product lines. The information contained in EPDs must be third party verified and compiled in line with international LCA standards.

Green building initiatives and other interested organisations in several countries have come together to form national EPD programmes to promote consistent development and wider application. Examples include Canada's EPDS, France's INIES/FDES system, Institut Bauen und Umwelt e.V. (IBU) in Germany, Italy's EPD Programme, Japan's JEMAI Type III Declaration Programme, EPD Norge (Norway), South Korea's Type III Labelling Programme, Swedish Environmental Management Council, the UK's BRE Environmental Profiles.

EPDs already provide a foundation for allocation of material credits in many national green building rating systems including LEED (U.S. and international), DGNB (Germany), BREEAM (UK and Netherlands) and HQE (France). France is phasing in a mandatory requirement for EPDs for all consumer goods.

Work is also being carried out on international harmonization of EPDs. CEN, the European standards institute, has developed the EN 15804 standard for construction sector EPDs and moving towards mandatory requirements for provision of basic EPDs for all construction products requiring CE marking.



In a parallel initiative, the ECO Platform supported by 25 EPD providers from 17 European countries is now working to harmonise national EPD systems based on the ISO 14025 standard. The first ECO Platform EPDs aligned to the harmonised procedures were issued in October 2014. Over 200 ECO Platform EPDs had been issued by the end of 2016 including several for wood panel and veneer products. International standards on EPDs require development of "Product Category Rules" (PCRs) for each product group to ensure that environmental assessments are performed in the same way and yield the same results no matter who does the analysis. PCRs for specific wood products have already been prepared by national EPD programmes in Germany, Sweden, and Norway.

In the UK, a single PCR document has effectively been developed to be applicable to all construction products including timber. The process is led by BRE through their "Approved Environmental Profiles" system which forms the basis of the BRE Green Guide and the allocation of credits for building materials in the BREEAM building rating system. Similarly in France, EPDs (referred to under the acronym FDES) for construction products must be prepared in line with an official French standard (NF P 01-010) which contains a single consistent set of PCRs for all products.

LCA AT THE HEART OF DESIGN AND GREEN SPECIFICATION IN THE EU

The EU has been a leader in promoting the environmental life cycle approach in design and product specification. As part of the EU "Single market for Green products" initiative, the EC has recognised that life cycle assessment should eventually become the foundation for all environmental product claims in the single EU market. The EU's Action Plan for the Circular Economy, launched in December 2015, also builds on life cycle principles and encompasses a wide range of actions to promote eco-design based on the reparability, durability and recyclability of products; energy efficiency; improved labelling that takes circular economy principles into account; circular economy criteria in green public procurement; improved waste management; and developing markets for secondary raw materials.

In pursuit of these aims the EC is developing a harmonised methodology for "Product

Environmental Footprints" (PEF) which draws on LCA procedures described in the ISO 14000 series and other international standards. The methodology is being pilot tested in a range of product sectors and work is underway to develop Product Environmental Footprint Category Rules (PEFCRs).

Looking to the future, it is likely that the PEF will become the standard European framework for life cycle based environmental profiling of consumer products while EN15804 conformant EPDs will be the standard framework for construction products, including structural timber.

LCA OF AMERICAN HARDWOOD LUMBER AND VENEER

AHEC involvement in LCA began in 2011 when thinkstep (formerly PE International) was commissioned to compile Life Cycle Inventory (LCI) data and an ISO14040-conformant LCA report for American hardwood sawn lumber and veneer. 'thinkstep' is an independent Germany-based company that is a leader in the acquisition and analysis of environmental data.

The goal and scope of the LCA on American hardwood lumber and veneer was defined as follows:

- **Functional Unit:** for lumber, one cubic meter of planed dry lumber of each commercial U.S. hardwood species and for veneer, one square metre of U.S average hardwood (species-mix) dried veneer.

- **System Boundary:** to include "cradle-to-gate plus transport" and covering all processes from extraction through to delivery to the importers yard in export markets.

- **Allocation was by value** so that the large majority of environmental impact is allocated to the finished American hardwood lumber and veneer rather than to low value (but potentially high mass) co-products like chips, saw dust and offcuts.

- **Cut-off Criteria:** any material or energy flow constituting less than 2% of the cumulative mass or energy of the life cycle inventory was excluded provided its environmental relevance is not a concern. In practice this meant that small items like thin wooden spacers used to separate boards during kilning were excluded.

- **Environmental impact categories:** quantitative data was provided on those impact categories for which there is strong scientific consensus on methodology and which are required in the EN15804 standard for construction sector EPDs, namely Global Warming Potential, Acidification Potential, Eutrophication Potential, Photochemical Ozone Creation Potential and Ozone Depletion Potential. A qualitative assessment was also provided on toxicity, biodiversity, land use and land use change, and water resource impacts.

- **Outputs would include:** an ISO-conformant technical report to be made publicly available on the AHEC website to underpin the credibility of the data; and life cycle inventory data which is publicly available and structured for distribution and use in GaBi and other LCA software.

In preparing LCI data for forestry and U.S. hardwood processing operations, 'thinkstep' drew on comprehensive research carried out in line with international standards over the previous decade by the Consortium for Research on Renewable Materials (CORRIM) with support of the U.S. Forest Service. The CORRIM LCI data was gathered in the field and is specific to the variety of forest and wood processing operations typical in different U.S. regions. Thinkstep also added a qualitative assessment of land use impacts drawing on data from the U.S. Forest Inventory Analysis (FIA) program and The Assessment of Lawful Harvesting & Sustainability of U.S. Hardwood Exports commissioned by AHEC from Seneca Creek Associates in 2008.

For sawn wood, LCI data was compiled for the following processing steps in the U.S.: debarking, sawing and kilning and (where relevant) steaming and thermal modification. thinkstep combined primary data sourced from detailed questionnaires completed by 46 AHEC members with data from 32 mills surveyed in the earlier CORRIM study. Data on standard industry kilning schedules was also drawn from the USDA Kiln Drying Manual.

For veneer, LCI data was compiled for the following processing steps in the U.S.: debarking, sawing, vat or wood conditioning of flitches and logs, flitch planing, slicing or rotary cutting, drying and clipping or trimming. Primary veneer mill data was collected by thinkstep using a questionnaire and during mill visits in 2012 from facilities across the eastern U.S. that together represent nearly 40% of national sliced veneer capacity and over 60% of rotary veneer capacity.

Thinkstep used GaBi software to build two LCA models, respectively for U.S. hardwood lumber and veneer, which describe all the processes to extract, produce and deliver product into export markets.

The GaBi model for U.S. sawn hardwood is highly detailed and unique data can be accessed for any one of the following 22 species which together account for at least 96% of total U.S. hardwood harvest: ash, aspen, basswood, beech, cherry, cottonwood, elm, hackberry, hard maple, hickory, pecan, red alder, red oak, sapgum, soft maple, sycamore, tulipwood, tupelo, yellow birch, walnut, white oak and willow. The model allows parameters to be adjusted to take account of variations in lumber thickness (which impacts significantly on drying times for sawn hardwood and therefore energy use).

The GaBi model for U.S. veneer provides data for U.S. industry average rotary veneer and sliced veneer respectively and is not disaggregated by species or thickness (which is less relevant to environmental impact for veneers than for sawn lumber).

To comply to ISO standards, an LCA must be subject to critical review by an external panel consisting of at least three members including one recognized LCA expert (panel chair) and additional members with either LCA expertise in the product sector being considered (in this case wood and/or wood products) or who are recognized experts in this sector. A review panel of exceptionally high quality was constituted for the thinkstep studies of lumber and veneer. Members included:

- Prof. Dr. Matthias Finkbeiner (Chair), who holds the chair for Sustainable Engineering at Technische Universität Berlin and is Chairman of ISO TC207/SC5 Life Cycle Assessment.

- Dr Richard Murphy of Imperial College London who is one of the world's foremost experts on LCA of wood products. He is currently Vice-Chairman of the EC COST E9 network on Life Cycle Assessment of Forestry and Forest Products.

- Pankaj Bhatia of the World Resources Institute (WRI), who is the Director of the GHG Protocol

Initiative workstream within WRI's Climate, Energy and Pollution Program (CEP). He is a leading expert on GHG Protocol Standards and tools, particularly in the area of corporate greenhouse gas (GHG) accounting and reporting.

According to the final statement of the Panel reviewing the LCA reports on both U.S. hardwood lumber and veneer concluded: *"The study has been carried out in compliance with ISO 14040 and ISO 14044. The critical review panel found the overall quality of the methodology and its execution to be of a high standard for the purposes of the study."*

LAND USE AND BIODIVERSITY IMPACTS OF U.S. HARDWOOD

A key conclusion of the 'thinkstep' LCA of U.S. sawn hardwood and veneer, and one that underpins many of the other environmental benefits of using American hardwood, is that extraction of U.S. hardwood has no negative effects on forest resources.

Drawing on analysis of regular U.S. Forest Service inventories, 'thinkstep' conclude 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, thinkstep conclude that: '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.'

AHEC DEMONSTRATION PROJECTS – BUILDING ON THE LUMBER AND VENEER MODELS

AHEC regularly engages in high-profile projects to demonstrate the technical, aesthetic and environmental advantages of designing and building in American hardwood. LCA is a key component of many of these projects as AHEC is keen to improve understanding of the process and to show how LCA allows robust environmental data to be integrated into the design process. The projects show that LCA offers a real opportunity to move beyond "greenwash" and to introduce the sustainability concept into product and building design in a meaningful and practical way.

Demonstration projects are also an opportunity for AHEC to build on the LCA data acquired for U.S. hardwood lumber and veneer and to explore the practical implications of using this data in the design and manufacture of buildings and products. American hardwood lumber and veneer are intermediate products with many different applications. Ultimately the impact of the material on the environment will depend heavily on the product design and manufacturing stages, and on the use and end of life stages, all of which are heavily dependent on the final application.

The extent to which designers and manufacturers can utilise LCA as a tool is highly dependent on their access to good quality information on the full range of products and materials. AHEC's efforts to provide LCA data on U.S. hardwoods to designers and manufacturers will be constrained if other material and product suppliers fail to provide equivalent data, or if designers and manufacturers are not provided with adequate guidance on how to utilise and interpret the LCA data. Guidance is also required on how to deal with tricky issues such as waste management, lifetime product use and maintenance, and disposal at end of life. Through demonstration projects, AHEC is building up a unique body of information which allows us to provide better guidance on LCA to any designer or manufacturer specifying or using a significant quantity of American hardwood.

In fact, AHEC's demonstration projects are highlighting that while LCA can be complex, the process is often relatively simple for any product manufactured or fabricated primarily from U.S. hardwoods. This is because much of the data required for such products has already been compiled in the studies on U.S. hardwood undertaken by 'thinkstep' and commissioned by AHEC.

The LCA data for delivery of U.S. hardwoods to the manufacturer need only be combined with a relatively limited amount of life cycle inventory data obtained from the manufacturer together with supplementary data contained in an existing database (like 'thinksteps' GaBi) or from EPDs from suppliers of other materials and components.

AHEC has established a simple procedure for collection of LCA data from designers and manufacturers engaged in AHEC demonstration projects. They need complete only two forms providing data for the functional unit in question (e.g. a specified chair or group of chairs, or a batch of doors or window units): the first form itemises all inputs of wood and other materials and the quantity and destination of waste materials; the second form records the quantity and source of power required to manufacture the functional unit. In practice, many designers and manufacturers already compile much of this data when calculating project or product costs and prices.

Drawing on this data and a relatively simple LCA model for the wood manufacturing process developed in GaBi, AHEC then produces a comprehensive LCA report for the demonstration project. These reports are providing insights into key issues such as:

- The relative contribution of different life cycle phases to overall environmental impact of projects and products using a high proportion of U.S. hardwood.

- The relative intensity and significance of different environmental impacts in those projects and products.

- The relative contribution of U.S. hardwood compared to other materials to overall environmental impact.

- The implications of different waste management strategies for overall environmental impact.

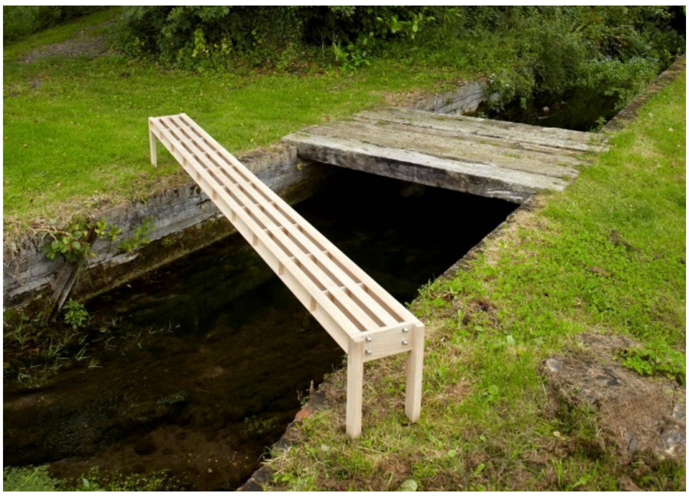
- The environmental impacts of large scale production relative to small scale bespoke or prototype production.

- The current quality of, and level of access to, LCA tools and to data on materials other than U.S. hardwood that is constraining uptake of LCA by the design community.

- Design strategies that are most effective to minimise environmental impacts.

LCA IN DESIGN

Designers are some of the most influential people on the planet – shaping the materials and products that we all consume.



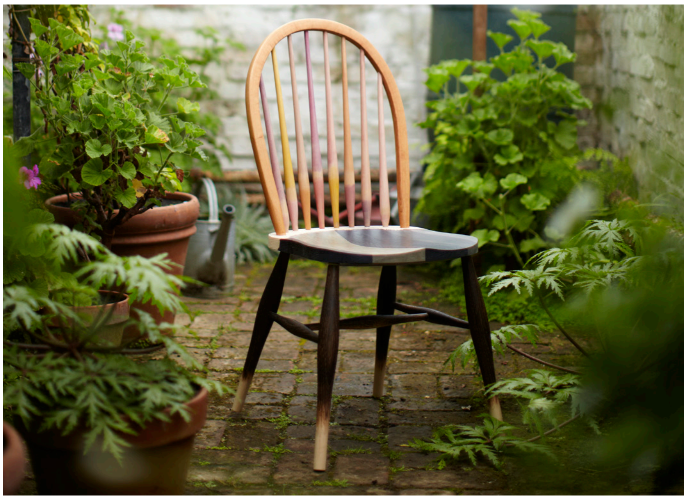
Designers have considerable power to influence environmental impact, for better and worse. However, they need to be empowered to make the right decisions through provision of reliable tools, data and guidance.

Concerted efforts are now being made to ensure that designers have comprehensive access to high quality LCA data and tools which are fully integrated within the traditional flow of product design activities. Progress is being made to integrate LCA data into Computer Aided Design (CAD) and Building Information Modelling (BIM) software and thereby allow life cycle environmental impacts to be assessed on the fly during the design process. Designers in the future will be able to amend designs so that they produce genuine sustainability gains before they go into mass production.

However, systems are still relatively primitive, lacking access to the full range of data on materials and products required. There's also often only limited understanding of how best to interpret the results. In the absence of more comprehensive tools, many designers and manufacturers, when seeking to improve environmental performance, still tend to rely on relatively simple assumptions or "rules of thumb" about good environmental performance, usually dealing with each environmental issues in isolation.

While there's nothing inherently wrong with "rules of thumb", it is important that they are rigorously tested and have a strong factual basis. In 2012, AHEC launched *Out of the Woods* - the first large scale AHEC demonstration project utilising LCA, which set out to test the validity of some of the most common assumptions about good environmental performance in furniture design.

Out of the Woods was a collaborative project bringing together AHEC's sustainable forestry and technical wood knowledge, the internationally renowned craftsmanship of British furniture producer Benchmark, the knowledge of art, culture and design inherent to the Royal College of Art (RCA) and 'thinkstep's' knowledge of environmental LCA and computer



modelling.

Twelve RCA students were each set the task of designing a chair with "sustainability" established as a key design requirement at the very start. Then they manufactured a prototype at the Benchmark facility recording precisely the amount of material and energy used. This data was entered into an LCA computer modelling system and combined with a large amount of other LCA data systematically gathered by thinkstep and AHEC on the environmental impact of all the materials and energy required.

Finally the computer modelling system generated a comprehensive environmental profile of each chair measuring environmental effects across a range of impact categories. The RCA students came to the project with a lot of assumptions about the best way of incorporating "sustainability" into their designs.

Some sought to revert back to nature, using unprocessed wood to reduce energy inputs. Some increased their reliance on recycled materials or the waste products of other processes, such as woodchips and offcuts. Some focused on creating classic relatively simple and durable products with a 'timeless' feel. They reasoned that these are more likely to be kept for a long time, even as tastes and fashions change, thereby reducing disposal and the need for regular replacement. Others took an opposing view and worked towards "dematerialisation", creating products which contain more air than matter. While not necessarily durable, these products can be disposed of regularly without creating much waste.

The environmental profiles generated for each design indicated that, in practice, no single strategy works in all contexts and for all applications. The project highlighted that there are always trade-offs and the challenge of design is find the appropriate balance for the specified application and location. For example, recycling may be best if there is a reliable and good supply of recycled material close to hand, but not if significant amounts of fossil-fuel based energy are required to separate out and transport this material to the manufacturer. Dematerialisation may be suitable for light-weight fashion items or cheaper furniture, but is hardly appropriate for products like benches that need to be weight bearing or around for many years.

Having said that, *Out of the Woods* and subsequent AHEC demonstration projects have revealed several "rules of thumb" to enhance environmental performance within the relatively limited context of products manufactured using a high proportion of U.S. hardwood. These are summarised in the box below.

DESIGNING IN U.S. HARDWOOD: 'RULES OF THUMB' FOR ENHANCED ENVIRONMENTAL PERFORMANCE

Using a high proportion of U.S. hardwood reduces carbon footprint: Due to the large amount of carbon stored in American hardwood, the carbon footprint of the American hardwood lumber delivered to the factory is almost always better than carbon neutral – irrespective of the transport distance involved. This means that other materials that may be less visible in the structure – such as steel fixings or plastic components - often have a disproportionately large environmental impact. Designs that avoid use of non-wood materials tend to have a better environmental profile.

Simpler designs often have lower environmental impact: Simpler designs using a high proportion of solid American hardwood which allow the wood to speak for itself and avoid the need for elaborate processing and finishing tend to have a low environmental footprint.

Prefer thinner boards when using slow drying species: Use of thinner boards tends to be better for the environment than thicker boards because the latter need to be in the kiln for longer and therefore require more energy during processing. This is particularly true of slow drying species like oak. From an environmental perspective, it's often preferable to glue together thinner boards rather than to specify thicker boards.

Create resilient and durable products: products designed in American hardwood for longevity tend to have a very low environmental impact. Long life in use significantly mitigates environmental impacts by reducing the need for replacement and therefore repetition of impacts. For products with a large U.S. hardwood content, there is the additional benefit that long-lived wood products supplement the carbon store in the forest and help to keep CO_2 out of the atmosphere.

Design with a view to minimising or utilising waste during manufacturing: LCA shows that waste management during manufacturing is often critical to the overall environmental profile. Efficient use of waste wood, either for other products or energy production, can go a long way to mitigating other environmental impacts. However sending waste wood and other materials to land-fill often has a significant environmental impact.

Focus in on energy efficiency during manufacturing: A relatively large share of carbon emissions and other environmental impacts of finished designs often occurs during the manufacturing stage, particularly if energy intensive equipment like CNC machines are used over long period and electricity is derived from a national grid with heavy dependence on fossil fuels. In these instances, measures to improve energy efficiency and reduce dependence on fossil fuels at the manufacturing plant greatly reduce environmental footprint.

Design with disposal in mind: minimising use of additives such as oil-based paints or large quantities of screws and other fixings, and favouring non-toxic and natural water-based treatments and finishes and non-chemical interventions such as thermal modification, makes for easier disposal at end of life and thereby significantly enhances environmental profile.