ASSESSING MATERIALS: METHODS OF DETERMINING SUSTAINABILITY

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1 INTRODUCTION

The reporting of climate change and environmental issues in both the general press and trade media has helped 'sustainability' become one of the buzz words of our generation.
Often the term is associated with everything that is deemed good and desirable but how does one assess how 'sustainable' a building project or construction product is?

In terms of what we call 'sustainable' a little bit of care and caution is needed, as it can be employed as a 'one term fits everything' phrase. The definition of sustainability that encompasses and balances the three strands of life: Economic, Social and Ecological, is by now likely to be familiar with most people [fig. 1], and there is rapidly growing interest and urgency to find ways how we can meet the environmental challenge that we face, in such a way that integrates both economic and social concerns whilst not compromising the planet for future generations to enjoy.

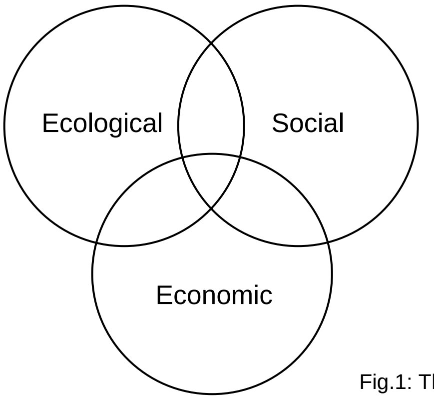

Fig.1: The three strands of sustainability

Assessing ecological sustainability in the construction sector is notoriously difficult as any project has a wide range of impacts: from energy consumption in use, through to the raw materials of each of the component parts, including transportation, waste, water and toxicity. As well as there being so many varied effects to measure, the measurements come in a disparate range of units, for example weight and volume, kWh, carbon dioxide and toxicity in levels of particulates. Typically, most of impacts are converted to give a summary result in terms of quantity of carbon dioxide but some issues, such as waste or toxicity, defy simple conversion.

To assess the impact of wood based composite boards (such as laminate or wood fibre board for example) there are a host of impacts associated with the production, despite timber being a renewable resource. The maintenance of forest plantations and the logging of the lumber will not only incur carbon emissions associated with the fuel used in pruning and felling, but further energy is used in transporting the lumber to a saw mill where it may be kiln dried, and milled. The timber pieces, or sawdust, may then be transported to another manufacturer where it may be combined with a bonding agent and may even be treated with both a mould and fire retardant. These chemicals could be toxic to aquatic life, and therefore there may be disposal issues with the off-cuts of the timber as they cannot be left to biodegrade due to possible leaching out of the chemicals.

Each aspect and stage of the manufacturing process (from water usage during production, to packaging and future recycleability and disposal of both product and packaging) can have a different combination of environmental impacts. With the myriad of impacts, each calculated in a different way, summarizing the overall impact of even one construction element can be tricky.

When considering materials as a part of a construction project, the issue of how sustainable a material is, becomes even more complex. Information on its longevity and how the product will be used in the building needs to be considered. For example: will it require additional materials to hold it in place, or does its use negate the use of toxic glues? Does it need to be regularly maintained or cleaned? Is it accessible and can it be easily replaced? All these aspects of a product need to be weighed up when considering its environmental impacts, as it may not require much energy to extract or produce but the energy used in maintenance and transport coupled with a short service life may mean that the material is less efficient than one which initially requires more energy during extraction and production.

All this makes it very clear, that assessing the environmental impact of a material and its influence on the overall sustainability of a construction project is not a quick task and not one that a designer or an engineer can be expected to investigate during the course of specification. It is a difficult enough science in its own right and one which is still being developed.

2 LIFE –CYCLE ANALYSIS

Life-cycle analysis (LCA), means looking at the environmental performance of materials over their entire life, and is a holistic way of assessing which products may be environmentally preferable. Life-cycle analysis should not be confused with the engineering practice of life-cycle costing (LCC). The latter takes into account the monetary outlays of acquisition, operating, maintenance, repair and disposal. Using the latter can determine benefits of initial outlays versus savings during operation.

The history of LCA can be traced back to 1960's when it was first used in the US, but it wasn't until the 1990's that LCA emerged as an environmental management tool in the form of the ISO 14040 series.[1] These ISO standards set out the principles, framework and requirements for LCA to international levels. The measuring of environmental performance of materials and products is an expanding business sector, and several life-cycle analysis software tools have been developed, including BEES in the States, and the BEAT tool in Denmark.[2,3] Some of the LCA software tools may have used different methodologies and varying assumptions but be equally valid. In the UK the Building Research Establishment (BRE), is the leader for sustainable construction expertise. The BRE acknowledges that there is no 'right answer' in applying LCA, and that there may be several different ways of determining LCA which can be used to asses construction products and materials, all of which meet the criteria set out in ISO BS EN 14040:2006 and ISO BS EN 14044:2006.[4]

Whilst LCA does set a standard for holistic assessment of environmental performance, there is still the problem of different measurables and units of the data, as described in the introduction above. To overcome this, the BRE developed their Environmental Profiles Methodology for Construction Materials and Components, which is consistent with the relevant environmental ISO standards. The Environmental Profiles Methodology normalises the LCA data, and gives a "level playing field" across every material type, and gives the impact of each material in a terms of a dimensionless ratio, which solves the problem of widely differing units between the disparate issues.[5]

The BRE Environmental Profiles methodology takes into account the following life-cycle parameters: maintenance, replacement, life-time use and disposal, as well as the environmental impacts of a material or construction product. The impacts of any given material, or product, are assessed by determining all of that particular material's inputs and outputs: such as the raw ingredients used, the transport, the fuel required and the manufacture of by-products.

<u>Example of 'outputs' for wood composite board:</u>

Outputs in this case may include any waste chemicals used as bonding agents, any packaging used for the boards, as well as any off-cuts or sawdust that is produced as a by-product in the manufacturing process.

The BRE Environmental Profiles Methodology stipulates inventory information to be collected on all emissions and discharges to water, air and land directly from the manufacturing processes and from fuel use. For example wood fibre board may be made with formaldehyde resin, which can be used to bond wood particles together. Formaldehyde emits VOCs into the atmosphere and continues to emit vapour even after it has hardened.[6]

<u>Example of Inputs for wood composite board:</u>

Inputs include all the product ingredients: in the case of composite boards – small pieces of wood and strong glue, resins or setting oils. The adhesives used in the product would also be included even though they may account for less than 2% of the output by mass, this is because adhesives contribute a significant proportion of energy input. Other additives used in small quantities but which are energy intensive to manufacture, such as Portland cement used in cement bonded particle board, would also need be included.

Transportation of the timber, adhesives or any solid fuels that are needed to be brought to the factory for the production process, is also included as part of the inputs of a wood composite board. The relevant proportion of the transportation energy burden is applied to deliveries where products form part of a split load. The percentage and nature of load on the return journey is also taken into account when calculating the burden of the transportation energy input of a material's ingredients.

The direct energy consumed in the manufacturing process: the fuel used by the factory machines and also that used for heating and lighting the factory and offices, as well as the water used in the plant are further inputs of wood composite boards.

The BRE Environmental Profiles Methodology set out how the inventory data of the environmental impacts is handled, and how the data is allocated into the various input or output categories. The collected information shows the energy and material flows of production, however it does not demonstrate <u>what</u> the environmental consequence of the inputs and outputs are. Therefore, the BRE classifies the inventory data into impact categories, according the data's environmental burdens, following international practice, according to the following scheme:[7]

Climate change	Pollution to water: Ecotoxicity
Acid deposition	Pollution to water: Eutrophication
Ozone depletion	Minerals extraction
Pollution to air: human toxicity	Water extraction
Pollution to air: low level ozone depletion	Waste disposal
Fossil fuel depletion and extraction	Transport and congestion: Freight

These environmental burdens are then normalised to reduce each impact to a dimensionless ratio, resolving the issue of the varying units of the impacts. 'Normalisation entails comparing the impacts arising from any activity (e.g. production of a tonne of material, production of a KWh of electricity, providing laundry services for a hospital for a year) with those from a common unit of activity- usually the impacts for an average citizen for a year… (and is)…calculated by taking the data on UK emissions, energy use etc, applying characterisation factors, and dividing by the population.'[8] The unit of measurement is Ecopoints, where the impact of the average UK citizen is 100 Ecopoints.

Environmental Profiles carried out by the BRE on building materials and construction elements are available to the public and can be found at: http://cig.bre.co.uk/envprofiles/document.jsp

For example:

1 sqm of wall as installed and built with Natural Building Technologies' 22mm Pavatex insulated sarking board with timber cladding, with 89mm timber studs filled with natural cellulose has been given an Ecopoint score of -0.02.

1 sqm of 35kg/m^3 Rockwool insulation, also in a timber framed wall construction but with brickwork and plasterboard, is given Ecopoint score of 0.44

Although the problem of varying units may be overcome by giving the results of in-depth Environmental Profiles which give the results as Ecopoints, it must be remembered that this remains simply an objective comparison between one material or element, and another.

Construction projects involve a larger picture – considerations of how a building is used and serviced are extremely significant. When choosing materials, Ecopoints can best help in comparing like for like. It can determine how additional insulation material, can (although in first instance adding to environmental burden as more of it is used) reduce the overall impact of building as less heating energy is required in the building.

Example: Case Study Princess Margaret Hospital (PMH) building

Carillion, lead partner in the construction of the building, in conjunction with the BRE used both LCC and LCA to develop the materials specifications in the design of the building.

The exercise looked at a two insulation types (polyurethane and mineral wool) and modeled 'how the environmental impact from the operation of the building (i.e. heat required to mitigate loss through the building envelope) may be reduced by approximately 18000 Ecopoints when the U-value is decreased. The number of Ecopoints embodied in the building envelope rose as extra insulation was used in the model but the overall Ecopoints for the building over its lifetime decreased for both insulation types.' [9]

	u-value = 0.45		***u- value = 0.22***	
	P'thane	*M Wool*	*P'thane*	*M Wool*
Installed fabric Ecopoints	*38 000*	*26 300*	*52 000*	*27 200*
60-year heat loss Ecopoints	*approx. 266 700*	*266 700*	*approx.248 900*	*248 900*
Total Ecopoints	*304 800*	*293 100*	*300 900*	*276 100*
Ecopoint saving			***-3 900***	***-17 000***

Combined with a LCC study it was found that the extra insulation would cost £21 000 but it would save £27 000 on the capital costs of radiant appliances on the top floor and save £213 000 in running costs over the building's life.

How efficiently buildings are when used is critical in reducing energy consumption, as approximately 40% of the UK's energy consumption is building related.[10] Using both LCA and LCC assessments cost-benefit ratios of environment conscious specification can be studied. However, construction projects have other effects, not just those arising from the choice of building fabric. Whilst LCA and LCC can inform our choices of materials, the design is critical in delivering sustainable projects.

Any building has a range of an even wider range of influences, some of them are almost intangible and certainly not quantifiable: How it does the building affect the community, does it foster social inclusion, is it accessible and does it respect cultural heritage? We know that some of these ‘intangibles’ are vital in terms of a project’s sustainability. Ultimately, if a building is unpopular or underused is not sustainable. If it is not used to its full capacity, or indeed does not serve its purpose, it will fail and could even be abandoned. Clearly, ensuring that all three - environmental, social and economic, strands of sustainability are included in a building project is vital. An office building that is built but for which the business case fails, can become a redundant superfluous building.

It is also important to see whether the building or development supports the user to lead a less environmentally damaging life. If the building overheats to such an extent that the occupant has to install air conditioning, the locally sourced-timber building may no longer be as sustainable as the light-weight structure may have led the designer to believe. Ultimately buildings are the shell in which human life and activity takes place, and it is the environmental impact of all these activities which ultimately are of concern. We are becoming aware that the rate of consumption in the 1st world cannot continue at the same rate and experts warn that natural resources are finite, and that the current level of resource exploitation cannot be maintained.

3 ECOLOGICAL FOOTPRINTING

Ecological footprinting is a method of environmental assessment that encompasses all these issues, building on the concept of how many people the planet can support. It was first developed in 1990 by Matthis Wackernagel, and embodies the concept of the ‘earth share’, which allows an individual’s footprint to be compared with the average supply. I.e. an ‘earth share’ weights demand against supply. Studies have shown that globally, the overshoot is roughly 25% but this masks the fact that resource consumption rates vary grossly between nations.[11]

If everyone globally lived like the average UK person, we would need 3 planets support ourselves. We need to address this gross disjuncture between available resources and consumption rate, and find a way of living with our fair ‘earth share’.

Using the findings from the footprinting methodology, WWF and BioRegional Development Group have developed the One Planet Living initiative, with the aim to enable everyone to live a good quality of life within their fair share of the earth’s resources.

All One Planet Living activities are based on the 10 Guiding Principles:

1. Zero carbon
2. Zero waste
3. Sustainable transport
4. Sustainable materials
5. Local and sustainable food
6. Sustainable water
7. Natural habitats and wildlife
8. Culture and heritage
9. Equity and fair trade
10. Health and happiness

BioRegional Development Group’s approach is to find solutions for sustainability, and the company has partnered with developers to build an international network of communities designed to the One Planet Living standard. These projects build on the learning that has come out of Bioregional

Development Group's BedZed (Beddington Zero fossil fuel development) community in south London.

The aim at BedZed was to enable residents to live within their fair 'earth share', and recent ecological footprinting studies have shown that at BedZed it is possible to lead a 1.2 planet lifestyle. This has been achieved not only through the architecture, with its carefully sourced materials, natural ventilation and rainwater harvesting features amongst other environmental design considerations, but also through the enhanced features of the development: such as the car club, the organic food boxes and allotments. The sustainable development at BedZed demonstrates the need to start thinking about architecture outside of the building fabric, and extending the thinking to creating communities that offer facilities which enhance and make a low impact lifestyle possible.

When BedZed was built, there was lots of interest from London political scene, and London's mayor, Ken Livingstone was keen to see more developments akin to the one at BedZed across all the London boroughs. However, since BedZed's completion in 2002, London has yet to build any of the desired zero carbon developments.

BioRegional Development Group has years of experience in mainstreaming sustainable projects and, following the BedZed project had identified barriers to mainstreaming sustainable developments:

- Developers lack the time to investigate, often new and somewhat unfamiliar, sustainable materials or building practices;
- there are perceived supply chain problems of sourcing sustainable materials;
- lack of knowledge and expertise as well as uncertainty of where to go for advice
- cost

To address these barriers, the concept of a sustainable buying club was conceived by Bioregional Development Group, and the charity carried out a feasibility study in late 2004, supported by the Housing Corporation, WWF and SEEDA. The study showed that there were clear benefits to be gained from pooling purchasing power to drive down cost, and using the collective purchasing power to send clear signals to suppliers to encourage competition and market penetration of sustainable materials. On the back of these findings, One Planet Products was established in 2005.

One Planet Products is led by the BioRegional Development Group and, enabled by start-up funding from Defra, works with partners in the construction industry to make sustainable products and construction materials available to the mainstream. It is a not-for profit, members-only a bulk buying group and knowledge exchange for sustainable products and services, targeted at housing associations and private developers. Bioregional Development Group, WWF and the BRE sit on One Planet Products advisory board and the club is staffed by a team of employees funded by membership fees. The product list is viewable on the One Planet Products' website. The website gives clear guidance in meeting EcoHomes targets (or the Code for Sustainable Homes when it comes into effect), as well as giving reports of water, energy and carbon savings against a product or material's mainstream alternative. Products and materials can be all be ordered through the club's website.

The club does not buy materials or products for, or on behalf of the membership body, rather it negotiates group discounts and rebates on behalf of the members with suitable suppliers. All purchasing happens between the Member and Supplier directly and One Planet Products does not interfere with the Supplier's usual terms and conditions of sale.

To get products or materials listed with One Planet Products, suppliers must complete application documents based on 10 One Planet Living principles. For suppliers, application and listing is free. The suitability of the products and materials is assessed internally, taking a holistic view of the supplier's robustness, as well as the environmental credentials of the product and supplier's discount offer.

Due to the complexity of the nature of LCA research, it is acknowledged that it is unreasonable to expect the design team to be able to carry out detailed information gathering to assess the relative environmental merits of building elements. Therefore, One Planet Products undertakes research on behalf of its members and integrates existing standards and LCA studies into the assessment procedure.

One Planet Products strives to push sustainability to the mainstream. It is not an accreditation body but rather a project that 'closes the loop', by giving practical help in support of developing One Planet Living communities. The club provides members with access to information and advice on environmental alternatives to mainstream construction products. One Planet Products considers the broad range of issues as set out in the 10 One Planet Living Guiding Principles, and thus ties together ecological, social and economic aspects of sustainability. In addition to giving information on both environmental and monetary savings associated with the products, the website highlights which One Planet Living principle characterizes each product.

One Planet Products lists Natural Building Technologies' wall systems and the Pavatex timber wall system with natural cellulose insulation (Ecopoint score of -0.02), has four main One Planet Living categories:

- Zero Waste
- Zero Carbon
- Local and Sustainable Materials
- Health and Happiness

As researching the environmental benefits of construction elements is a lengthy process, and not one which can easily be undertaken during the time pressures of a building project, the information on products listed with One Planet Products has proven to be of much interest to architects, engineers and specifiers. Due to considerable interest from this sector of the construction industry One Planet Products is in consultation to develop a specific Membership tailored to architects, specifiers, consultants, and engineers.

The One Planet Products website gives the listed suppliers a direct route to market, saves members both time and money.

For more information please visit the website at:

www.oneplanetproducts.com

or email: info@oneplanetproducts.com

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