Environmental Assessment of Building Materials and the Green Guide: where do we go from here? Neil May

Environmental assessment of building materials and systems is a vital part of our understanding of how buildings, people and nature interact, either in positive or negative ways. The effect of buildings and the construction process in regard to major issues such as climate change, energy use, resource depletion, pollution, habitat destruction and human health is increasingly apparent. However, while there is a growing understanding of energy and carbon issues in building use (mainly through research from outside the UK), there are still considerable gaps in our basic knowledge and understanding of the more complex issues of embodied energy and carbon, of functionality and of the effects of building materials and processes on the environment and on human health (see Appendices 1 & 2 for further explanation of these difficulties).

For this reason, we think it is too complicated and potentially confusing at the moment to try to provide a complete environmental impact assessment of building materials and systems which is used to determine what people can and cannot use in their buildings. Indeed, such an assessment could be potentially damaging to buildings, human health and the environment as well as a possible barrier to innovation and change. It was because of this danger that the Good Homes Alliance produced its Critique of the BRE Green Guide to Specification in November last year.

The GHA's Critique of the Green Guide

Tthe Good Homes Alliance critique of the BRE Green Guide to Specification, was based upon the information which was available on the website and through some informal discussions with BRE. We had serious concerns in regard to

- The **critical lack of transparency** in both methodology and data.
- The **flawed methodology** in relation to the use of Generic Profiles, Elemental Profiles, the A+ to E rating system, the weightings used, the way that carbon sequestration was calculated, the selection of building types and categories, and the omission of elements and categories
- The **unintended negative consequences** of the many and compounded flaws in methodology, particularly for good design, for overall environmental impact of buildings, and for innovation in environmental products and systems.
- The potentially serious **legal issues** of prejudice, trade restriction, competition and redress.

This was not meant as a criticism of environmental assessments of building materials per se. It is vital that these continue to be developed both in terms of data and methodology in a fully transparent manner and there is already good work underway in specific areas, especially in indicating how environmental impact could be made accountable in the future. However there is still considerable further work to be done in many areas before assessments should be used as planning or legislative tools, or as an effective "Bible" for specifiers, as the Green Guide often is.

BRE's response to the GHA's Critique

Since the release of the GHA paper, BRE have published a lot of information about the methodology, so that it is clearer, although in some areas still difficult to understand. They have also stated publicly that

"The specifications shown throughout the Green Guide should not, however be used as a basis for on-site construction. They are of generic nature only and are used to illustrate a range of typical materials. Although every effort has been made to ensure that the information given here is accurate, our knowledge and understanding continues to evolve." (Green Guide Home Page).

On December 1st 2008 they also stated the following in News from BRE:
"It is important to note that if different criteria and/or weightings are used in any methodology then the relative performances of materials or products could change to a considerable degree." The News continues "There is a range of choices within ISO, including an option to look at future uses where recyclability (cradle-to-cradle) rather than recycled content has a greater emphasis, which can produce significantly different results. No choice is 'more right' than any other but the selected interpretation should be transparent and based on the goal and scope of the study."

Furthermore they state that "It is important that users of the Green Guide have a proper appreciation of what it is and also what it is not, as well as some understanding of how it works. Without this basic knowledge there are risks that users will simply use it as a tick box activity and not look more carefully and holistically at the Green Guide itself, the CSH and BREEAM within which it sits."

On the website the following has also appeared: "The Green Guide is intended for use within whole building assessment tools such as BREEAM, the Code for Sustainable Homes and EcoHomes rather than as a stand alone tool. Material choice and specification has impacts on the overall environmental, social and economic impact of a building which the Green Guide cannot take into account. For this reason, BRE does not recommend that targets based on the Green Guide ratings are set independently, for example by Planning Authorities."

There is even a section on the FAQs on the website where it states the following:
"In June 2008 BRE Global launched the basic Green Guide online as a free to view service. The scope of this service will be enhanced over the coming year, and will incur subscription costs. Coverage is expected to include:

- Accessibility of numerical LCA data on specifications and the capability to switch between Green Guide ratings and numbers
- Environmental impact specific numbers including information on resource efficiency and carbon footprint
- A specification and material search function
- Access to proprietary and manufacturer specific LCA data and its influence on Green Guide ratings
- Per ton generic material environmental impact information
- Graphical interfaces and displays
- A 'build your own specification' tool
- A mixing desk in which material supply and production options can be examined"

GHA views on BRE's response to the Critique

All of the above changes are very good in our opinion, although it is a shame that the enhanced service which will include the transparency of some of the data will be a chargeable service.

However this attempt to address some of the underlying flaws in the Green Guide is still a step too far. It is trying to mend something that needs a radical rethink. Our concerns about basic aspects of the methodology (such as the A+ to E ratings, the use of Generic profiles, the use of Build Ups, the selection of categories, the particular use of functionality, the issue of carbon sequestration etc), the outcomes of the guide whereby every build up in whole sections such as external wall masonry systems achieve A+ ratings, and the effects of the guide on design, performance and innovation - these concerns still remain.

In light of the difficulties in nearly all areas of assessment (just two of which difficulties are illustrated in the appendices to this article) and in relation to the still unclear and under-researched area of whole-building performance, it seems evident that we should go back to first principles in relation to the environmental assessment of building materials. The principles, which will enable us to move forward, are:

- Simplicity
- Integrity/ Rigour
- Learning

Environmental assessments must be simple in order to be achievable and understandable. They must have integrity or rigour in science, data and in transparency. And they must integrate learning as in an ongoing process of research, monitoring and feedback in which all parts of the industry are involved so that assessments are used intelligently and correctly to deliver real reduction in environmental impact overall in construction and building performance. The transparency issue is perhaps the most important starting point, as without full free transparency of data, none of the ratings or assumptions can be understood or interrogated, and no actual learning about impacts of materials can take place in the industry.

Update of the GHA position

Following on from these and the current state of knowledge it seems clear that the requirements for a proper and effective environmental assessment of building materials are

- A significant and fully funded research programme to establish more firmly the basic science of environmental impact
- A significant and fully funded research programme to establish basic accurate data
- Public ownership of the data, science and assessment methodology, independent of industry and government
- Transparency of data and assumptions in all areas
- Single product based assessment only and therefore the abandonment of use of multi-product build ups <u>at the moment</u>. Generic profiles should only be used with caution where there is sufficient evidence that all products have similar impact.
- On the other hand the evolution of tools for specific whole system or whole building analysis should be developed.
- Abandonment of the Green Guide or any environmental assessment tool for use as a statutory or planning tool until evidence based data and an evolved science is available. This should be publicly announced and enforced.

It is quite possible that the BRE Green Guide data and science could be the basis for such a project. It would be folly to throw away the great amount of work and learning that already exists. However it would also be detrimental, in our opinion, to continue to use the Green Guide as it is now and to promote it as "accessible and reliable information [which] will be of great assistance to all those involved in the design, construction and management of buildings as they work to reduce the environmental impact of their properties", as it states on the home page of the Green Guide website. It is not accessible, nor is it of great assistance in reducing environmental impact. In fact it may be having the opposite effect.

The environmental impact assessment of building materials is too important to leave in this current state. In our opinion there should be a huge amount of resource put into this area in a co-ordinated, expert and ideally publicly owned venture. This should not be in the ownership of a private organisation such as BRE, although they should surely be involved. It should be owned by Government or a collective body on behalf of the industry. If we want a responsible industry, with responsible sourcing of materials and reduced environmental impact, then we must have responsible structures and responsible funding. This is too important a task to be left to private and competing under-funded initiatives. It is time that Government realised the importance of this issue and acted boldly to set the whole industry on a more scientific and evidence-based footing, with a proper structure and proper funding.

Neil May 16/04/09

Appendix 1: Difficulties with Embodied Carbon

It is very unclear at present how much embodied energy or embodied carbon is present in buildings, and therefore how important embodied energy and carbon are in relation to energy and carbon in use. Carbon is particularly difficult to assess, as will be shown. Most current assessments are based on partial evidence and on only partially understood science. One of the best and most commonly used analyses of building materials is the Inventory of Energy and Carbon (ICE) produced by Prof Geoff Hammond and Craig Jones of Bath University (Version 1.6a 2008). However as the introduction makes very clear there are considerable limitations to the data, particularly data about embodied carbon, which, according to the Inventory, is provided usefully only in about 20% of data sources. Most of the carbon data is based on calculations taken from the embodied energy and then converted according to assumptions about types of fuel used, which could lead to great variations in embodied carbon, as made clear by Hammond and Jones.

In regard to both embodied energy and embodied carbon the introduction states "There are several available open inventories similar to this one. Comparisons of the selected values in these inventories would show many similarities but also many differences. It is rare that one single value could be universally agreed upon by researchers within this field of work." This is reinforced in the actual analysis of different materials where the range of values (from least to most) in embodied energy per kg in the raw data commonly varies by a factor of several hundred, and in the "best range" of "selected values" by a factor of up to 15 (for example cement had an overall range of 0.1 MJ/kg to 11.73 MJ/kg and a best range of 2.8 MJ/kg to 6.8 MJ/kg; ceramics have the same overall and best range of 2.5 MJ/kg to 29.1 MJ/kg). As the Inventory states in regard even to the selected data "the selection of the range and the best values of embodied energy was not an easy task, especially with so many holes in data provided by authors". Furthermore the criteria for most of the materials assessed are cradle to gate rather than cradle to site or cradle to grave, which involve even more unknowns and uncertainties and in many cases may be the most important factor in assessing actual carbon or energy impact (certainly in low energy bulk materials such as aggregates). Overall the Inventory is a fantastic source of information, but as the authors are keen to point out, it should be used with care. And furthermore it should be remembered that it is based on secondary sources only, using a variety of methodologies.

Some of the best whole building analysis comes from organisations such as Davis Langdon, who recommend the ICE data as one of the best, if not the best source of data about embodied energy and embodied carbon. A case study produced by them in Feb 2008 estimates that a particular Low Energy Office building (fabric only) as designed has over 1 tonne of embodied CO_2/m^2 of footprint, which would equate to 23 years of carbon emissions in use for this particular building. However while this is an interesting exercise, the use of incomplete and variable data means that this kind of assessment is limited in use at the present time unless data is properly related to real impacts which is a costly and difficult task in many cases. This problem of real data is identified by Davis Langdon as a key development requirement in the case study. What this exercise does provide, however, is an excellent model of how we might assess buildings in the future.

However, even with better traceability of materials and more accurate extraction manufacturing, transport, site and waste data, there are also considerable scientific issues of uncertainty in relation to certain materials which have a huge effect on embodied carbon calculations. The most important area of uncertainty is in relation to bio-renewable materials (ie grown materials), the foremost of which is wood, but also including crops such as wheat straw, hemp, flax and animal products such as wool. The reason why this is an important area is both that there is a very large amount of timber, in particular, used in construction, and furthermore bio-renewables absorb carbon dioxide from the air when growing and so potentially act as carbon sinks, locking up carbon and reducing the total amount of CO2 in the atmosphere during service, therefore potentially helping to alleviate global warming. However while the actual lock up of carbon is reasonably well understood, the assumed service time of the materials and in particular the end of life assumptions about the materials make a huge difference to calculations of how significant this carbon is both in relation to the other impacts of construction, and to total national or global emissions.

The amount of carbon locked up in bio-renewables such as timber is mainly through proteins and carbohydrates. In softwoods for example about 500kg of Carbon (effectively1800kg of CO2) is locked up per tonne of timber. From this it is easy to calculate the tonnage of CO2 locked up in buildings with softwood components (for example an average sized 3 bed timber frame house of a certain type may be calculated to lock up around 20 tonnes of CO2 in its frame). It is even possible to calculate the amount of CO2 involved in felling, converting and transporting timber to site for specific projects and specific wood sources. However the problems about calculating the carbon impact of timber in buildings are related not so much to the use of timber but to the service life and the end of life assumptions about timber, ie when and how and in what form stored carbon is released into the atmosphere.

In assessing the carbon impact of timber in buildings assumptions have to be made about the length of life of the building and the final destination of the timber elements – re-use, recycling, combustion for energy, combustion only for disposal, composting. At present the average life of a building in the UK seems to be a little over 100 year (though most calculations including that of the Green Guide assume 60 year life only) and at the end of life a large proportion of timber goes to landfill. However this could change radically in the next few years as the legislation and infrastructure around waste changes.

The questions that are critical are: how much timber is sent to landfill, and how much *will* be sent to landfill (as opposed to being burnt productively, re-used or recycled) at the end of life of the timber ie in about 100 years time? In land fill how is timber composted now and how will it be composted in the future (as this makes a huge difference to emissions – aerobic composting releases very little methane, whereas aerobic releases a lot of methane)? How much of the composting timber (or any bio-renewable) is actually decomposed and released as gas (as opposed to remaining as fibre or being absorbed into other matter)? How much is released as methane and how much as CO2? How much of the methane is or could be recovered and burnt productively?

In regard to the decomposition, this is where the science is very unclear. We have seen different evidence presented which proposes that anywhere between 3% and 50% of timber will be decomposed and released as global warming gases. This difference is considerable and will vastly change the total lifecycle impact of timber, just as assumptions about whether timber is re-used, recycled, put to landfill, or burnt in some way in 100 years time will vastly change the impact. Assumptions about the relative amounts of CO2 and Methane released in the composting process are also vital. At present it seems that many assessments assume a 50:50 split, which is probably correct for landfill anaerobic decomposition. However if this varies even slightly the effect on global warming will be considerable as methane has 25 times the global warming potential of CO2.

Depending on the assumptions that are made it can be shown that the use of timber in buildings is either an incredibly good way of sequestering carbon, or in fact makes no difference at all because of the CO_2 and methane released on disposal. It is actually quite possible that timber, on the assumptions used for the Green Guide, has a negative effective overall on global warming. For example if you assume most timber goes to landfill and that there is 50% decomposition with 50:50 ratio of CO_2 to CH_4 (methane) then 1 tonne of timber will release the equivalent of more than 3.5 tonnes of CO_2. If the service life is only 60 years rather than 100 years plus this becomes even worse. Of course if you change these assumptions timber and all bio renewables can become really good means of long term carbon sequestration. However the point is that there is still a great deal of uncertainty. It is still not entirely clear even whether woods (whether natural or managed) are carbon neutral, negative or positive (and here the sustainability of production may be critical). The fact is that many biological processes are not fully understood, many chemical processes are not fully understood, and the future of buildings and of building waste is uncertain.

It would be very rash therefore to attempt to assess and provide legislatively binding or influential ratings for bio-renewables or indeed any building material (as these must be compared with bio-renewables) in terms of their global warming potential without considerable further research. This research is required both into the behavior and fate of bio-derived carbon and also into the data of all materials in terms of embodied carbon and embodied energy. We also need to look closely at incidental waste in production and on site to get a true picture of the actual rather than the theoretical impact of processes and materials.

Appendix 2: Difficulties with Functionality

Another area of considerable difficulty in the environmental assessment of building materials is functionality, which is critical if comparison is to be meaningful. It is relatively easy if products with single functionality are compared. However it is much more difficult if products are multi-functional and it is even more difficult if building systems are to be compared, as these are nearly always multifunctional. How does one compare systems to take into account the functionality of thermal performance, acoustics, structural qualities, fire performance, weathering, and health? Of course it may be argued that one functionality is primary or is the primary variable in certain situations, but even then, it may be the other functionalities that carry the greater environmental impact.

Of course most functionality is the result of whole buildings not of one element within buildings. This is particularly the case in regards to thermal performance, which is used as a prime functional criterion in the Green Guide.

The problem with using thermal performance as the main or sole functional criterion is that thermal performance is actually relatively complicated. Thermal performance is not just a function of the thermal resistance of a building element. The actual energy performance of a building (ignoring human behaviour) will be highly influenced also by thermal mass (calculated as admittance and decrement delay), by thermal bypass, and by the airtightness of a building.

Even thermal resistance is not straightforward, as the thermal resistance of a system will be hugely affected by the amount of thermal bridging in that system which will vary in terms of the building form (corners, junctions, etc) openings, and the structural requirements (for example panelised systems will have varying amount of structural members according to the structural requirements of the building). Repeating thermal bridges are taken into account in U values, and non-repeating thermal bridges are calculated as psi values which are aggregated together to produce y values for the whole building. As the non-repeating elements of buildings change with each building form, it may seem reasonable only to compare systems on the basis of U values. However some systems are far better at dealing with non-repeating thermal bridging than others. For example systems where the insulation wraps the structure in an unbroken layer will be much better than those where the insulation is broken up by the structure. So for example a timber frame wall construction with insulation in between studs may have as much as 30% full thermal bridging of the insulation whereas a timber frame with all of the insulation on the outside of the frame will have 0% thermal bridging. The U values could be the same (according to the amount of insulation on each), but the y values would be hugely different as would the actual thermal performance of the building. Of course the actual thermal performance would also be hugely affected by the total thermal performance of the roof and floor, including not only the thermal resistance and thermal bridging of these elements, but also the junctions between the elements, the thermal mass, the amount of thermal bypass, and the airtightness.

Furthermore if one is setting a functional criterion of thermal resistance there is the issue of what level this is set at. If it is set at a very high level (say Passiv Haus standard) rather than at a base level (say 2002 building regulations U values) then the systems that will achieve this easily and with least environmental impact may be completely different to those that will best achieve the lower level. This is because some systems are better suited to low energy houses than others.

Finally there is the complex issue of actual performance in reality. It is beginning to be realised now that most buildings perform much worse in reality than in design. The work by Leeds Metropolitan University on Stamford Brook, which is the only really extensive and detailed research on mass building in the UK in the last 30 years, showed that building heat loss on this development was typically 100% more than designed. This heat loss continues to worsen as airtightness in the buildings also worsens each year. It may well be that heat loss is far worse in general in new buildings in the UK than on this highly monitored development. So the choice of thermal resistance as a functional unit needs to be related to reality not just theory. How do systems really perform? How important is thermal resistance in theory if it does not relate to reality? How do different systems integrate airtightness and other key performance factors in reality on today's sites? Finally if we can't get the building impact in use sorted out, why are we confusing everyone with embodied impact which doesn't and in many cases cannot actually take functionality properly into account?