Embodied energy - a ticking time bomb?

Part 2

In this, her second article on the subject, Kate de Selincourt explores methods and tools available to designers and builders wanting to count – and cut – the embodied energy and carbon impact of their buildings, and considers whether carbon 'locked up' in biological materials - like timber and straw -- should be credited in the foot-printing process.

In this article 'embodied' is used in the more standard convention, to mean 'impacts that have already happened, represented by the product here now'. In this usage, 'embodied' carbon is therefore an emission – and confusingly, is not contained in the 'body' of the product. Carbon that is contained in a material, previously absorbed and now kept out of the atmosphere, is described here as 'sequestered'.

In the last issue of Green Building we saw how embodied energy and carbon emissions are becoming more conspicuous as operational impact is falling. We also saw that as most of the embodied impact happens at the start, carbon emissions from construction accumulate proportionally more 'tonne years' of global warming impact – making them even more significant.

There are not yet specific embodied impact or life cycle impact standards for buildings, but eventually there will be – if not standards, then certainly benchmarks, and client expectations. So, designers and builders will want to know: how can I check I have minimised the embodied carbon and energy of my build as far as I can?

The simplest tools are online calculators where you key in the building size and construction type, and get a rough readout of embodied impact. Not all of them are transparent about their assumptions and data sources, but they might be a place to start – perhaps to give a sense of relative embodied and operational emissions. For an example see the Phlorum embodied CO_2 estimator visit: http://eco2.phlorum.com/calculator/index.

For a little more accuracy, it is possible to 'build up' pre-set specifications. The BRE Green Guide offers some, though BRE's specifications do not cover foundations, services or some fitout. BRE also includes the end of life impact – the Alliance for Sustainable Building Products (ASBP) questions the methodology used for this, saying it makes unfavourable assumptions about biological materials.

Alternatively the Hutchins Blackbook gives figures for embodied impact based on the ICE cradle-to-gate approach[1] - though the methodology is not explicit. It costs around £150.

The approaches above can only handle conventional constructions. For more flexibility and/or to study a refurbishment, you have to go back to first principles, and add up the separate quantities of all materials. At this stage many firms call in a specialist, but it is also possible to 'do it yourself'.

Bruce Bell and his colleagues at Facit Homes compared cradle-to-gate impact for three different construction approaches, including their own, using the ICE database, plus manufacturers' data where available. Bell liked the ICE database "because it is clear and open about what is counted, and shows you exactly how the figures have been arrived at."

Their calculations suggested that for a 160m^2 house, the light construction might be responsible for 47 tonnes of embodied CO_2 less than in a conventional structure – a substantial cut.

Doing some sums offers instructive surprises and shows that gut instincts are not always right. For instance, Bell's hunch that insulation choice wouldn't make much difference was proved wrong; and when Gareth Roberts of Sturgis Carbon Profiling analysed a proposed timber roof he found an unexpectedly large impact from the glue used in the lamination – fixed by a simple change of glue.

Designers need to share and learn together

As Bruce Bell says: "What is important is to do the sums - but these comparisons are not easy to do. We spent a long time creating conversion tables because so often the embodied impact is given 'per kg' or 'per m^3' which is no use at all to a building designer". Facit Homes want to share its results, and would love to see a library of analyses built up, so learning can be shared. "I am happy for others doing similar work to contact me. We want to share what we are doing," says Bruce Bell, Facit Homes, who can be contacted via info@facit-homes.com.

Data sources

Anyone with enough patience could do a similar exercise, and it is equally applicable to new build or refurbishment. Data sources include the ICE inventory (about £60) mentioned above (see link at end of article). For free, BRE offers generic materials LCAs and specific 'environmental product declarations' – although not everyone agrees with the BRE approach, and many would like more transparency. (BRE's Tim Barrow-Williams was challenged on this at the 2012 Ecobuild, and agreed there was a case for transparency).

None of these datasets are anything near perfect. Some data in the ICE inventory show very wide ranges, for instance, others may not be recent. Individual product declarations may be more accurate – but don't tell you about alternative products that might be substituted.

Life cycle analysis gives a fuller picture

Cradle to gate studies ignore the impacts of a building as it is built, occupied, then demolished. To fit in with the latest European standards, a full life cycle analysis (LCA) has to include the construction process and fitout, the operation of the building, cleaning and maintenance, repairs, renewals and refurbishments, and finally demolition/deconstruction, and also the final fate of the materials (be it re-use, recycling, incineration or landfill). It therefore gives a sense of the knock-on implications of each choice.

As life cycle expert, Jane Anderson, puts it, "Building elements are interdependent so it is important to assess all aspects … This is particularly relevant if designing out building services, or using additional materials to produce a zero carbon solution."

Integrating the impacts from the present, the building's life, and even its ultimate demise, is the internationally accepted way to go, but not everyone likes to combine the real present with the imagined future. Craig Jones, author of the ICE database, is one, pointing out that even carefully modelled operational emissions are only based on current 'state of the art', and energy efficiency, and carbon intensity, may change significantly in future.

The further the analysis looks into the future, the less precise you can be, and the more issues arise about what can be combined with what. (See also section on 'Should 'carbon in the bank' receive a credit?' on page 52.)

But, the process of making the analysis is worthwhile. It should highlight where improvements can be made, and

TIMELINE	STAGE	QUESTIONS TO CONSIDER	
Cradle to gate	Extraction of raw materials Transport and processing	Whole building including fixtures, services etc? Do your quantities include % anticipated waste, or will this be accounted for separately as a site impact? (NB the QS's BoQ usually excludes waste.)	
		FACTORY GATE	
Site	Transport to site	Impact per km, heavy greater than light, road much greater than sea.	
	Site activities	Lights? Pumps? Temporary structures?	
	% Wastage	Can be 10% or more. Some materials worse than others (rain, tolerances, etc), Is an assumption already included in your cradle to gate totals? Can the contractor give you data from their last build? Can the impact be lessened? If you are publishing data after completion, are you going to adjust the impact to reflect what really happened – for better or for worse….?	
		HANDOVER	
Operational	Operational energy use (heating, cooling, services, appliances etc)	Are you presenting modelling for actual consumption by building separately from any renewable generation? (and of course, separately from any offsite 'allowable solutions').	What is your assumed building life? Standard LCA tools set standard figures – do you want to carry out parallel calculations with a figure you feel is more appropriate?
	Cleaning, repairs and maintenance	Eg: different floor finishes need different cleaning requirements. Paints/varnishes etc all have energy and climate impact.	
	Replacement and refurbishment (structure, finishes fittings, services etc)	Site impacts including wastage etc? Disposal impact of replaced elements?	
		Databases (eg. from cost consultants) are available giving estimated lifespans. Frequency of refits? Huge issue with commercial buildings, especially retail.	
		END OF LIFE	
End-of-life	Demolition	Most of the impact is indirect, ie, the care taken to allow reuse & recycling.	
	Disposal	Re-use, recycling, incineration (in energy plant), landfill, incineration (on bonfire), (Contested definitions/assumptions for impacts of all the above!) Not necessarily meaningful to include in building total (unknown, and depends on next use) but qualitative report aids good design. Quantities are required for some LCA standards, however.	

flag up 'unintended consequences' where an apparently good choice leads to an undesirable impact elsewhere.

Design teams in larger organisations can call on the services of colleagues, such as cost consultants already geared up to add up component parts (in a bill of quantities). Many also model costs for the lifespan, including maintenance and replacement ('whole life costing'), so can help predict the impact of repairs, renewals and refurbishments. RICS (Royal Institute of Chartered Surveyors) is working to get the 'cost control community' more involved.[2]

A new generation of LCA tools

Some 'new generation' life cycle analysis tools are being developed with assistance from the Technology Strategy Board. Designers, engineers, quantity surveyors and software specialists have teamed up to develop tools to help these disciplines to collaborate, and communicate, more fluently.

Instead of working in isolation, hopefully all will be able to see the implications of their decisions on the others' 'fiefdoms'. According to James Todd at Architype, involved in developing one of these tools (provisionally called 'Rapier'), the idea is to bring together inputs from all, without needing to hire in a consultancy, who might not be able to respond quickly (or cheaply!) enough to guide the crucial early decisions. Very basic building 'concepts' can supposedly be compared while they are being discussed (even via a smartphone!). More specific detail can be input directly from design software such as SketchUp or Autodesk – to give increasingly detailed impact estimates.

Other tools include 'Butterfly', from a consortium led by BLP Insurance, and IMPACT led by BRE. BRE Wales is also developing an embodied and sequestered carbon calculator specifically for plant-based materials in a building. Different tools are furnished with different databases and energy models, though many also give users the opportunity to customise.

This all sounds great – but the designers are the first to admit that the tools will probably need users to trial and refine them. The creators of Rapier for example are inviting volunteer testers; BRE Wales are also looking for (Welsh) testers. (See 'Further reading and links' at the end for contact details).

Whatever the process, it is important not to be seduced by the appearance of certainty that figures can convey. As Gary Newman from the Alliance of Sustainable Building products puts it: 'don't use them as a substitute for thinking'

Plant-based materials- a special case?

Materials like wood, straw and hemp are sometimes seen as special cases, because when the plant grows, it absorbs carbon dioxide and 'locks it up' into what becomes the building material.

In fact many biological building materials already boast lower embodied carbon than their processed alternatives, without taking this into account. The Hutchins Blackbook gives an embodied CO_2e of 5-7kg/m^2 for timber cladding; for a brick skin, it gives 86kg/m^2.[3]

Timber, as a construction material, offers more energy and carbon benefit via replacing concrete, bricks and steel than it yields when burned directly for fuel. A study for DECC[4] compared the benefits of using UK timber instead of, for example, concrete or plastic, to make things, versus using all the timber directly for energy.

The calculations suggested that the emissions saved by using wood in products instead of alternatives were anything from 3-10 times more than from using the timber directly for energy. Perhaps that is unsurprising when you consider how elegantly designed trees are. Nature's genius has an energy value as well.

Should 'carbon in the bank' receive a credit?

The 'manufacturing' difference alone justifies the use of biological materials to many. However, there is also a school of thought that sequestered carbon should count as a 'negative emission' or 'credit', as many plant based products contain more carbon in their mass than has been emitted in the production chain. Some would like to credit that negative in the overall footprint, and some already do, saying, for example, the timber in a construction 'makes the project carbon neutral for the next 30 years.'[5]

There is no question that carbon sequestration is valuable. One of the reasons for protecting forests, after all, is because of the huge quantities of carbon locked into the living material, out of the atmosphere. If a tree is felled and built into a house, then another tree can be grown – and you could eventually see a net increase in carbon storage – clearly a good thing. And interest in this harvested store is likely to grow. The UNFCCC meeting in Durban agreed that stocks of 'harvested wood products' are now to be reported by all Kyoto signatories .[6]

An average British house already contains between 6 and 12m^3 timber[7] – which might be equivalent to 5 -10 tonnes of sequestered CO_2. Why not increase that - and it could be considerably increased[8] - and if the designer and builder go to the effort of using a higher proportion of wood, why not award carbon 'credits'?

Different LCA and product rating systems deal with

Photo courtesy of Cooke Industries Ltd

Straw and timber lock up carbon - but should this be subtracted from the other impacts?

sequestered carbon in different ways, though none of the formal systems simply subtract the sequestered carbon from the overall footprint. Some, such as PAS 2050, allow for an averaged negative CO_2e over the time the carbon is sequestered. Systems for building products more often offer a 'snapshot' of whatever might be left after 100 years – which, in practice, largely depends on assumptions about waste disposal, perhaps less of a fair picture of sequestration over time. After these calculations, an LCA report may bundle these results into a single 'carbon footprint' of a building.

Not everyone agrees that it is appropriate simply to subtract the sequestered carbon from an embodied carbon total for the building. Bruce Bell is clear where he stands: "You can't include sequestered carbon. I think it's a bit like doing carbon offsets, and people can dispute the way this is counted."

These questions go to the heart of the way we set our standards and targets, what we report, and, crucially, how we think about the impact of our activities. Is it right to allow an increase in the global carbon store to 'cancel out' the emissions from, say, the manufacture of concrete or glass used elsewhere in the building?

Carbon offsetting, where companies attempt to 'hide' some of the impacts of their operation (like burning jet fuel) behind various carbon saving or carbon-sequestering projects, is treated with scepticism. There is also a case to be made that single-figure operational carbon standards (in the UK, the Code for Sustainable Homes and so-called 'zero carbon') have allowed designers to 'hide' weak fabric performance behind quantities of renewable 'bling', and/or an aristocrat's share of local timber production put through a biomass boiler – but end up with an apparently low impact.[9]

Is 'offsetting' embodied carbon emissions from construction with sequestered carbon in the fabric any different? As with most oversimplified targets, the potential for unintended consequences is built in. With an impressive tonnage of 'carbon negative' timber, there's a temptation to feel maybe a self-indulgent window here or a cheaper choice of masonry there 'has been made up for'.

On top of this, 'offsetting' often relies on assumptions about what has happened, will happen – or even what will not happen – in another sector, away from the building designer's control. As Bruce Bell commented: "It's difficult to justify and not very empirical. I don't think you can start back tracking about something that happened in the past, somewhere else".

Sequestered carbon in materials is only 'negative' if forest or farmland carbon stocks remain constant. Though this is supposed to be the case with 'sustainably sourced timber' – it's still an assumption. But also, it is only negative if the use of the product here does not decrease the use somewhere else. If you used enough timber in one building to build three, meaning the other two get built from steel and concrete instead, that might not be of carbon benefit at all. To answer this, you need to know a great deal about international timber markets.

On top of this, sequestration in buildings is not permanent, so any accounting system has to allow for changes in stores over time.

A more direct approach might keep these elements separate, and track them all over time. The AECB's paper 'Less is More'[10] suggests that in order to have a realistic overview, changes to carbon stores should be recorded via 'profit and loss accounting'. Different stores have different stabilities, and are affected by different processes, so they need separate accounting.

DECC does publish carbon balance sheets[11] but it is not easy to tell from these what has gone in and what has gone out, or why. Perhaps what is needed is an annual profit and loss report and set of balance sheets for soil, forest, fossil fuel, harvested biological products, etc, year on year – what is added, and what is lost, by both natural and human-driven processes. Predictions and assumptions would then be reported separately, not 'rolled in' to obscure real, current events.

Carbon accounting for individual activities – such as constructing and operating a building - would enable us to understand how the built environment was actually contributing on all the indicators, as well as helping to identify genuine best practice.

An LCA may include many of these factors. The different elements can be kept separate, and any assumptions can be made explicit. Operational emissions can be reported separately from embodied emissions, and these can be reported separately from sequestered carbon. Grid electricity consumption and fuel burning should be predicted separately from each other and from renewable generation; emissions from biomass burning should be reported as emissions from biomass burning, with assumptions about compensating biomass growth made separately and explicitly.

Keeping the elements separate enables meaningful benchmarking and specific and flexible target-setting. Perhaps the next step would be to write an LCA more like a movie script, a year at a time, and to return each year to record how things turn out in reality. That would be something to see.

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Refs.

1. BSRIA Guide to Embodied Carbon, Prof Geoffrey Hammond & Craig Jones. Cradle-to-gate means materials from extraction of resource through manufacture, until it leaves the factory gate.

2. https://consultations.rics.org/consult.ti/embodied _ carbon/viewCompoundDoc?docid=2598132&sessionid=&voteid=

3. Hutchins figures quoted by Historic Building Scotland

4. Carbon impacts of using biomass in bioenergy and other sectors - forests, 2012: www.decc.gov.uk/en/content/cms/meeting _ energy/bioenergy/strategy/strategy.aspx

5. 'Bridport house, East London' Oliver Wainwright, Building Design, 11 May, 2012

6. Piers Sadler 'Carbon sequestration by buildings': paper for ASBP

7. Figures from Stewart Milne

8. Piers Sadler as above

9. Nick Grant, paper on 'Zero Carbon', International Passivhaus Conference 2012 (in press)

10. 'Less is More': http://aecb.net/news/

11. See, for example: www.decc.gov.uk/assets/decc/11/stats/climate-change/2758-mapping-carbon-emissions.pdf

Further reading & links

- *Guide to understanding the embodied impacts of construction* www.constructionproducts.org.uk/publications/technical/display/view/a-guide-to-understanding-the-embodied-impacts-of-construction
- For information on WRAP's successful 'designing out waste' initiative see: www.wrap.org.uk/category/sector/construction
- ICE (Inventory of Carbon and Energy) www.bsria.co.uk/bookshop/books/embodied-carbon-the-inventory-of-carbon-and-energy-ice/
- Project Rapier www.projectrapier.com
- Project Butterfly www.blpinsurance.com/sustainability/butterfly/
- IMPACT www.bre.co.uk/page.jsp?id=2181
- BRE Wales embodied/sequestered carbon tool: for information contact Martin Brocklesby, brocklesbym@bre.co.uk

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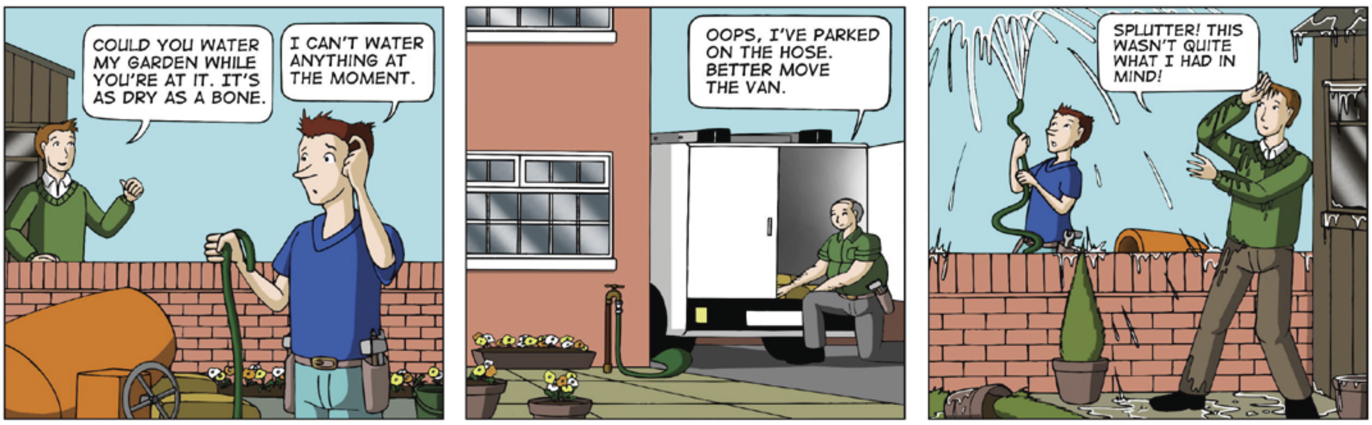

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