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Embodied Energy

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Definitions: Embodied Energy and Embodied Carbon

Think about the wide range of materials and products used in constructing our buildings today. They are made by extraction of raw materials, processed, manufactured, transported to site, and constructed as the finished building – the energy associated with all these steps and processes is what makes up the **embodied energy** of the building and its materials. This can also be expressed in terms of the carbon dioxide emissions associated with this embodied energy, defining the term **embodied carbon.**

The other energy usage associated with our buildings is that used in running the building services and other equipment in the building over its lifetime – this is known as the **operational energy** consumption for the building. The associated operational carbon emissions from the building services are the basis of Building Regulations Part L (see TBN 19). The embodied energy, and the operational energy for the building over its whole life, can be added together to create a **whole-life carbon footprint** for the building, perhaps the most comprehensive way to look at the environmental impact of the energy and carbon associated with our buildings.

Why is Embodied Energy important?

With much tighter Building Regulations, and improvements in construction standards such as air-tightness and increased insulation, new buildings are becoming more and more energy efficient. Use of low and zero carbon energy supply on-site, such as PV panels and solar thermal hot water systems, further reduces the operational carbon emissions associated with new buildings. This means that, in terms of the total whole-life carbon footprint of our buildings, the embodied energy and carbon emissions are becoming much more important in relative terms. The graphs below shows typical data for the embodied and operational energy for two different levels of typical construction for new homes over a lifetime of 60 years [1].

Diagram 1: Energy Consumption for a Typical Three-Bed House

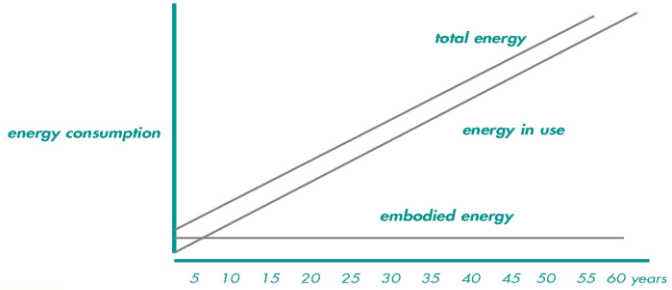
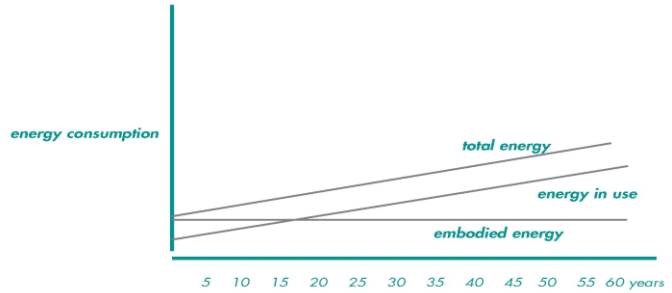


Diagram 2: Energy Consumption for a Low Energy House



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For the 'typical' house embodied energy is ~10% of the total over its life, whereas for the 'low energy' house the embodied energy is 30-40% of the total.

For non-domestic buildings is has been estimated that the embodied carbon in a distribution warehouse was 60% of its total lifetime carbon footprint, whereas a supermarket, which uses a lot more energy, has an embodied carbon content of 20% [2].

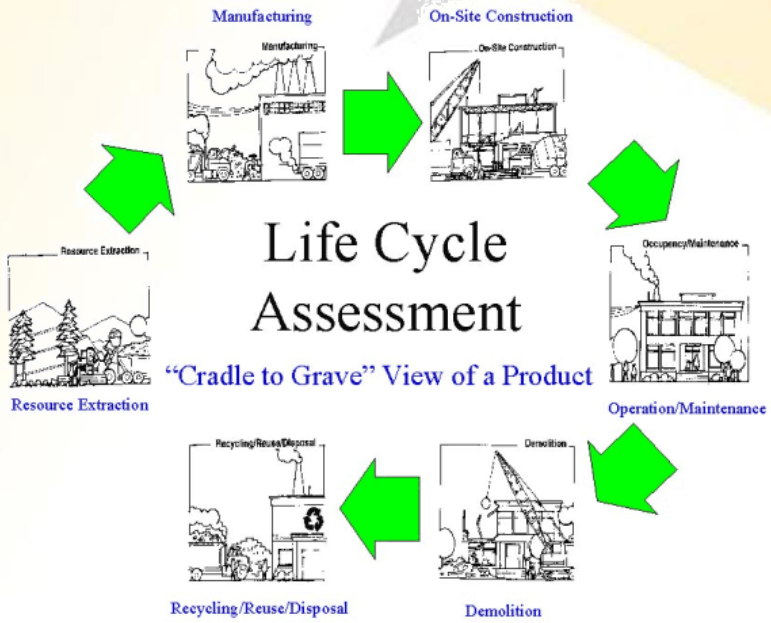
At present Building Regulations Part L provide the minimum regulatory framework for operational energy/carbon emissions from buildings. Currently there is no regulation of embodied energy/carbon in UK construction but a recent government policy report[2,3] has suggested that this should be brought in the regulation framework at some time in the near future once suitable standards for definition and measurement have been established. Ahead of this several clients and construction bodies are already active in promoting the use of embodied energy. British Land, for example, has calculated embodied energy/carbon data for its new Ropemaker Place office development[2]. In this case embodied carbon represented 42% of lifetime emissions and operational carbon 58%.

What is Life Cycle Assessment?

The embodied energy of a typical building product is derived from the energy associated with the steps in its **lifecycle** from extraction of materials, through processing and manufacture, to transportation and construction, and in some cases its eventual disposal and reuse/recycle – this is often termed 'cradle-to-grave'. The process of analysing and quantifying all these steps is known as Life Cycle Assessment (LCA).

The diagram below[4] illustrates this in simplified terms for a typical manufactured product.

Embodied energy is just one of the environmental impacts associated with a building product's lifecycle; others include extraction of materials, water usage, pollution and toxic by-products from production etc.



LCA is the basis of the assessment of sustainable materials and is at the heart of standard reference methods in this area. One such example is the BRE "Green Guide to Construction" which is a database of the LCA of a variety of construction products. The Green Guide rates each product

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on an A+ to E ranking system, where A+ represents the best environmental performance/least environmental impact, and E the worst environmental performance/most environmental impact. The Green Guide, and the related Certified Environmental Profiles, for specific materials also form the basis of material credits used in BREEAM assessment and the Code for Sustainable Homes.

How to measure Embodied Energy

The most difficult issue facing policy makers and the construction industry is that there is currently no single agreed standard method for assessing the embodied energy of a construction material or product.

The base data for embodied energy has been compiled by sources such as BRE (see above) and Bath University, which is used by RICS and others currently developing tools to help the industry assess embodied energy more consistently.

There are many tools and models currently available or under development that can calculate the embodied energy for a specific building design and bill of materials, including:

- BRE's ENVEST software which is currently being revised
- 'Redefining Zero' model developed by RICS, Sturgis Associates and DCarbon8 launched in May 2010
- 'IMPACT' tool being developed by a group including IES and WD Re-Thinking
- BLP Whole Life Cost tool which is being extended to cover embodied energy and carbon impacts

There are plans to create one common European system via the standards process CEN TC350 group. Any future regulations including embodied energy will refer to the standards developed under this process.

Embodied Energy – Examples

The following examples show how the embodied energy of alternative materials compares for some typical construction alternatives, based on an LCA which covers 'cradle–gate' processes which excludes transportation and construction process impacts[5,6].

Masonry walls – expressed in mass terms

Material	Embodied Energy MJ/kg	Embodied Carbon kg CO^2/kg
Bricks (common)	3.00	0.22
Concrete block (150mm medium weight)	0.71	0.08
Aerated block	3.50	0.30
Rammed earth	0.45	0.02

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Masonry walls – expressed in volume terms

Material	Embodied Energy	Embodied Carbon
	MJ/m3	kg CO^2/m3
Bricks (common)	5100	374
Concrete block (150mm medium weight)	1349	152
Aerated block	2625	225
Rammed earth	657	34

Timber products - expressed in mass terms

Material	Embodied Energy	Embodied Carbon
	MJ/kg	kg CO^2/kg
Timber (general)	8.5	0.46
Glue laminated timber	12.00	0.65
Sawn hardwood	7.40	0.47
MDF	11.00	0.59
OSB	9.5	0.51
Plywood	15.00	0.81

Structural elements – expressed in volume terms

Material	Embodied Energy	Embodied Carbon
	MJ/m3	kg CO^2/m3
Glue laminated timber	9600	520
Steel (typical virgin/recycled)	190320	13806
Concrete (1:1.5:3 eg in-situ floor slabs, structure)	2664	382

Insulation – expressed in volume terms

Material	Embodied Energy	Embodied Carbon
	MJ/m3	kg CO^2/m3
Rockwool (slab)	403	25
Polystyrene insulation	2215	63
Polyurethane insulation	2163	90
Straw bale	25	1

Limitations and Pitfalls

When looking at alternative material/product choices, it makes sense to look at all aspects of a material's overall environmental performance. Embodied energy is only one aspect of this, and one where examining the source and nature of the data used is particularly important.

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References and further information

1. The Housing Corporation (2000), 'Sustainable Homes: Embodied Energy in Residential Property Development'.
2. Thomas Lane (4th June 2010), 'Embodied Energy', www.building.co.uk
3. Low Carbon Construction Innovation & Growth Team (Spring 2010), 'Emerging Findings'
4. http://www.concrete.net.au/LCA/lca/lca.php
5. http://www.greenspec.co.uk/html/materials/embodied_energy.html
6. www.bath.ac.uk/mech-eng/sert/embodied/

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