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ENERGY EMBODIED & OPERATIONAL

TARGET AUDIENCE & OBJECTIVES: This document introduces and briefly describes the concepts of used and embodied energy, how they can be quantified as well what are the tangible benefits from minimising their consumption. This paper is intended for construction professionals, people working in local governments and the general public which have an interest in the notion of construction sustainability and how it can be influenced by energy use.

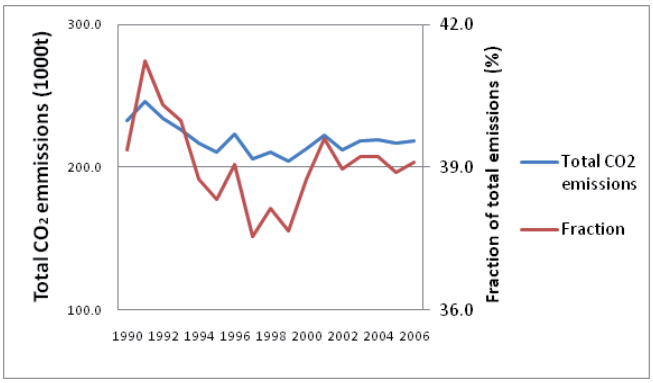
Overview

The consumption of energy, particularly through the combustion of fossil fuels, has been linked with negative environmental impacts such as air pollution and climate change.

Presently the built environment constitutes one of the highest consumers of energy within the UK. In 2007 the residential sector was the second highest energy end-user having increased its energy consumption by almost 20% since 1970[1].

When accounting for the energy consumed in non-residential buildings, these figures become even higher. At the moment roughly 40% of the total CO2 emitted in the UK is coming from buildings. As a result the reduction of energy use within the built environment has been considered a cornerstone of a shift towards greater sustainability.

Figure 1: Total CO2 emitted from UK buildings and its fraction when compared to the total national emissions[2,3].



In 2003 the EU put forward the Directive on the Energy Performance of Buildings (EPBD)[4] which has been incorporated into Scottish legislation, from 2005 onwards, through the Scottish Building Standards[5]. These legal instruments attempt to:

a) set minimum requirements for the energy perform -ance of new buildings and existing large buildings that are subject to renovation;

b) promote the certification of all buildings.

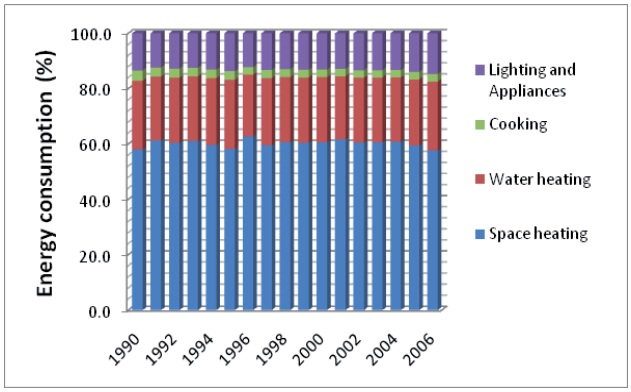
Definitions

The amount of energy used for the construction and operation of a building can provide a good indication of the environmental impact of the building over its lifetime. At the same time, the energy consumed during the operation of a building represents one of the most important running costs.

Currently, there are different ways of accounting for energy consumption in buildings. The two most popular are the energy used (or energy in use) during the operation of the building and the embodied energy of the building.

Used energy is the energy directly consumed for the operation (running) of the building. A number of different activities are relevant with lighting, space heating and water heating being the most important.

Figure 2: Energy use by different activities in the residential sector[2].



Determinants of the amount of energy used are the technology of the appliances as well as the use patterns by the residents.

Embodied energy, on the other hand, is a more complicated concept that refers to the total energy that has been consumed directly and indirectly in the construction of the building. This includes both the energy required on site during the construction phase, as well as the energy that has been required to extract, manufacture and transport the materials used.

Maintenance can also contribute significantly to the overall embodied energy of the building. The replacement of damaged or worn off building elements adds up to the overall embodies energy of the building. However this is not currently being considered in the calculation of embodied energy suggested by the UK Building Research Establishment (BRE).

It is estimated that the energy embodied at the new construction and renovation accounts for about 10% energy consumed in the UK each year with approximately half being used in the extraction and manufacture of the materials and half being used in transport[6]. Other studies suggest that upto 40% of the life cycle energy of a building is embodied[12,13].

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How to measure it

Considering the different nature of energy used and embodied energy, a number of tools can be used to account for the energy consumed in buildings.

In 2007 the Scottish Government introduced legislation which made the energy performance certification of buildings mandatory through the issuing of Energy Performance Certificates (EPCs)[5]. This legislation, however, refers only to the energy used during the operation of the building. The accounting tools for the quantification of energy used which are currently approved from the Scottish Government include:

- New built dwellings: the Standard Assessment Procedure (SAP)
- Existing dwellings: the reduced data Standard Assessment Procedure (rdSAP)
- Non-dwellings: the Simplified Building Energy Model (SBEM)

These tools mainly account for the energy used in buildings for heating (space and water), ventilation and lighting purposes. For example, the SAP rating (1-100) is calculated by adding the energy used for space heating, water heating, ventilation and lighting and subtracting it from potential energy savings through the adoption of energy generation technologies in the building.

Embodied energy is a more complex concept to quantify because it is concerned with the energy consumed in the production and transport of the building materials. The most appropriate way to measure the embodied energy of the building materials is Life Cycle Analysis (LCA). A complete LCA can be a very resource and data intensive procedure that is influenced to a great extent by the spatial and temporal boundaries adopted.

For example LCAs that adopt a "cradle-to-gate approach" (i.e. from extraction of the raw material to the manufacture of the finished product), or a "cradle-to-site" (from extraction of the raw material to the use of the finished product on site) or a "cradle-to-cradle" approach (for recycled material) will inevitably produce different embodied energy results.

At present there is no Scottish legal requirement regarding the embodied energy per se in buildings. Nevertheless such considerations have indirectly permeated into the Scottish construction industry through the adoption of the BRE Environmental Assessment Method (BREEAM) suite of tools[7]. One of the indicators measured by these tools is the environmental impact of the building materials. This is usually calculated by reference to the environmental ratings of the materials used in the building, and which have been calculated by BRE through extended LCAs[8].

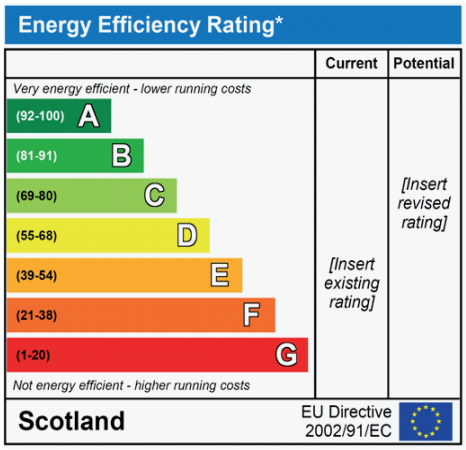


Figure 3: Energy Performance Certificates for residential buildings [5].

Fig 4a: Energy consumption in a conventional house[6]

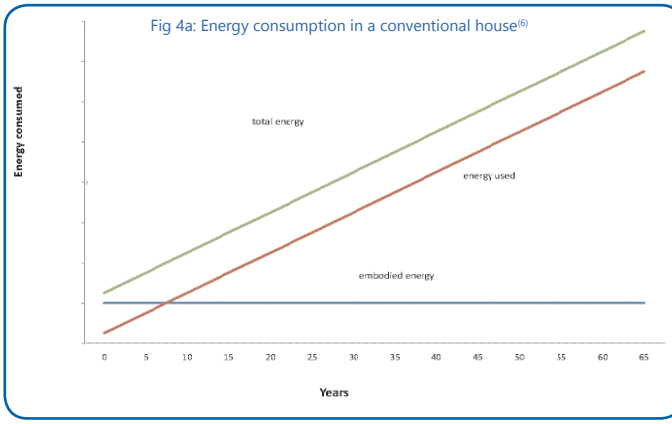
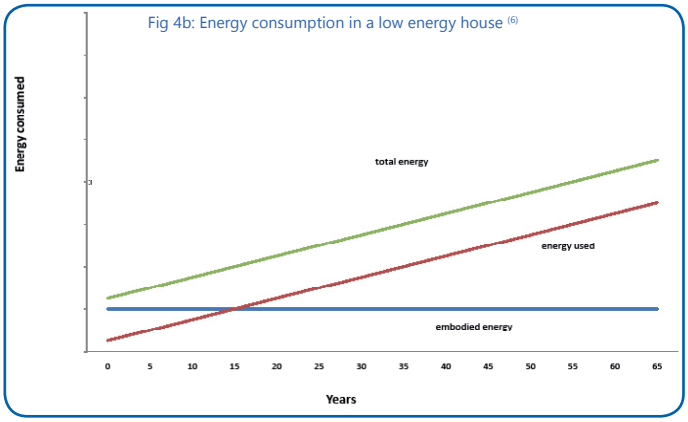


Fig 4b: Energy consumption in a low energy house [6]



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Reducing energy use: advantages & disadvantages

Environmental concerns have been the most potent driving forces behind the adoption of policies for the conservation of energy in the built environment. It has been estimated that an average UK household produces around 6 tonnes of carbon dioxide every year, which could be reduced by around two tonnes with minimal effort[9] (e.g. minor changes in the use of domestic appliances). Additionally, energy use in the built environment is a major source of atmospheric pollutants such as particulate matter, nitrogen oxides and volatile organic compounds which are detrimental both to human health and ecosystems. A decrease in the energy used during the operation of the building will result in smaller emissions of carbon dioxide and of most atmospheric pollutants.

The second advantage of reducing energy use is also the most appealing to the users themselves. Generally speaking lower energy use results in lower running costs. Some of the potential ways to achieve this include the change of consumption patterns, cavity wall insulation, loft insulation, double glazing, efficient boiler systems, energy rated appliances and generation of energy on site. The Renewable Energy Centre has compiled a list of the different options along with their average installation costs and savings[9].

The third advantage of energy conservation reflects the general energy security and sustainability concerns that stem from the increasing scarcity of fossil energy resources. Lower embodied energy materials can be more environmentally friendly and save significant cost to the manufacturer. Nevertheless it is difficult for the end user to appreciate the amount of energy embodied in different building materials if they are not labelled. According to the Housing Corporation, "...the general rule is to buy from as local a source as possible, particularly for bulky materials"[6].

The table opposite includes embodied energy values for different building materials that were collected in the Inventory of Carbon and Energy (ICE)[8].

Table 1: Embodied energy (EE) and embodied carbon (EC) of different building materials. (refer to info sheet S-POL2 for more details on embodied carbon)

Material	EE (KJ/Kg)	EC (Kg CO2/Kg)
Aggregates	0.1	0.05
Aluminium cast products		
- virgin	226.0	11.70
- recycled	24.5	1.35
Asphalt	2.6	0.05
Bricks - common	3.0	0.22
Bricks - faced	8.2	0.52
Cement	4.6	0.83
Cement with mortar (1:4)	1.2	0.18
Ceramics – general	10.0	0.65
Ceramics - fittings	20.0	1.05
1:1:2 Cement-sand-aggregate	1.4	0.21
1:4:8 Cement-Sand-Aggregate	0.7	0.08
Glass	15.0	0.85
Fibreglass	28.0	1.53
Insulation - general	45.0	1.86
Insulation - glasswool	28.0	1.35
Paint - single coat	10.2 MJ/m2	0.53 KgCO2/m2
Paint - double coat	20.4 MJ/m2	1.06 KgCO2/m2
Plaster - gypsum	1.8	0.12
Plaster- plasterboard	6.8	0.38
Steel bar and rod		
- virgin	36.4	2.68
- recycled	8.8	0.42
Timber	8.5	0.46
Plywood	15.0	0.81
Windows- aluminium framed	5470.0	4.79
Windows- timber framed	230.0 - 490.0	12.00 – 25.00
Windows - PVC framed	2150.0 – 2470.0	110.00 - 126.00

The most commonly adopted strategy for conserving energy, either energy used or embodied, has been the improvement of energy efficiency. However, it has been suggested that increases in energy efficiency might actually result in greater energy consumption. This is called the "rebound effect" given that increased energy efficiency generally makes the use of energy relatively cheaper, thus encouraging its increased consumption[11].

The existence of potential rebound effects implies that technological solutions are not enough to reduce the energy used in the built environment. The active attempt of the consumers to reduce their energy demand through the modification of their consumption patterns and behavioural change seem to be equally important.

REFERENCES

No.	DESCRIPTION	LINKS
1	"BERR - Energy consumption in the UK.	http://www.berr.gov.uk/energy/statistics/publications/ecuk/page17658.html
2	"BIS - Energy consumption in the United Kingdom.	"http://www.berr.gov.uk/energy/statistics/publications/ecuk/page17658.html"
3	UNFCCC website. Type: various resources within the website	http://unfccc.int/2860.php
4	"European Commission - Directive 2002/91/EC on the Energy Performance of Buildings	http://www.managenergy.net/products/R210.htm
5	"SBS - Scottish Building Standards Type: website "	http://www.sbsa.gov.uk/index.htm
6	"Sustainable Homes - Embodied energy in residential property development.	http://www.sustainablehomes.co.uk/upload/publication/Embodied%20Energy.pdf
7	"BRE - BREEAM: the Environmental Assessment Method For Buildings Around The World.	http://www.breeam.org/
8	"BRE - The BRE Green Guide to Specification	http://www.bre.co.uk/greenguide/page.jsp?sid=435
9	"The Renewable Energy Centre - A Guide to Energy Saving in the Home.	http://www.therenewableenergycentre.co.uk/press_release/A_Guide_to_Home_Energy_Saving.pdf
10	"Hammond and Jones, 2008 - Inventory of Carbon and Energy (ICE)	http://people.bath.ac.uk/cj219/
11	"UKERC - The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency.	http://www.ukerc.ac.uk/Downloads/PDF/07/0710ReboundEffect/0710ReboundEffectReport.pdf
12	Thormark C. A Low Energy Building in a Life-Cycle - Its embodied energy, energy need for operation and recycling potential. Build Environ 2002; 37:429-435.	
13	Chen TY, Burnett J, Chau CK. Analysis of Embodied Energy Use in the Residential Building of Hong Kong. Energy 2001; 26:323-340.	

FURTHER INFORMATION

TITLE	DESCRIPTION	LINKS
BIS	UK energy statistics	http://www.berr.gov.uk/energy/statistics/index.html
Department of Energy and Climate Change	Exchaustive information on UK climate and energy policy	http://www.decc.gov.uk/
SBS	Scottish Building Standards	http://www.sbsa.gov.uk/index.htm
IEA	"The International Energy Agency (IEA) is an intergovernmental organisation which acts as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens."	http://www.iea.org/about/index.asp
European Commission	Energy policy across the EU member states	http://ec.europa.eu/energy/index_en.htm
OPSI	UK energy legislation	http://www.statutelaw.gov.uk/SearchResults.aspx?TYPE=QS&Title=energy&Year=&Number=&LegType=All+Legislation
DEFRA	Contains a wealth of information on climate change and energy, as well as the current UK policy	http://www.defra.gov.uk/environment/climatechange/
IPCC	Exchaustive information regarding the impact of energy use on climate change	http://www.ipcc.ch/
BRE	Sustainable construction portal	http://www.bre.co.uk/page.jsp?id=9
BIS	Sustainable construction portal	http://www.berr.gov.uk/whatwedo/sectors/construction/sustainability/page13691.html
Hammond and Jones, 2008	Inventory of Carbon and Energy (ICE) for different construction material	http://people.bath.ac.uk/cj219/
UKERC	"The UK Energy Research Centre is the focal point for UK research on sustainable energy. The website contains information about energy use in the built environment"	http://www.ukerc.ac.uk/Home.aspx
Scottish Government	Energy policy in Scotland	http://www.scotland.gov.uk/Topics/Business-Industry/Energy
Energy Saving Trust	"The Energy Savings Trust is a NGO that provides free impartial advice to save energy in the house"	http://www.energysavingtrust.org.uk/
Canadian Architect	Embodied and operating energy in buildings	http://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_intro.htm
Green Building Focus	Report on Carbon Reductions in buildings	http://www.greenbuildingfocus.com/default.aspx?id=464
UK Green Building Council	"The UK's Green Building Council aim is to dramatically improve the sustainability of the built environment, by radically transforming the way it is planned, designed, constructed, maintained and operated."	http://www.ukgbc.org/site/home
CLC	"Energy Performance of Buildings. New measures to improve the energy performance of UK buildings."	http://www.communities.gov.uk/planningandbuilding/theenvironment/energyperformance/
BRE	Standard Assessment Procedure (2005) for the calculation of the energy performance of buildings.	http://projects.bre.co.uk/sap2005/