Section 1: Why Sustainable Construction?

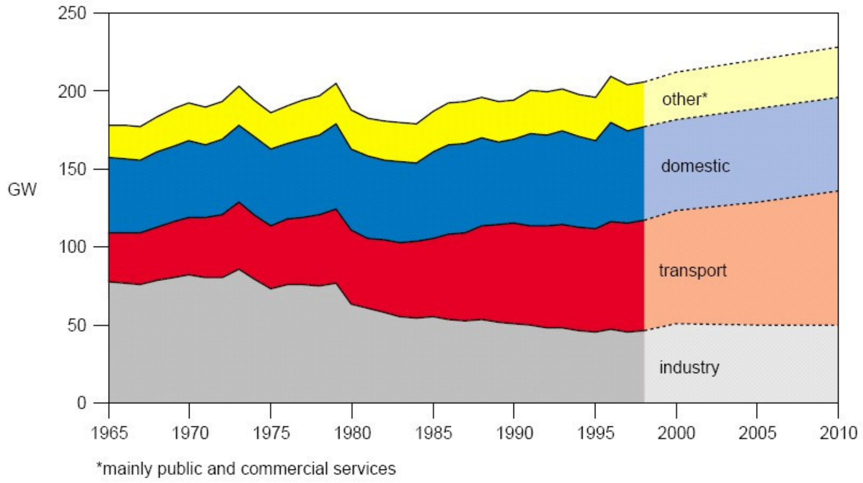
It is clear that the quality of our built environment, like the quality of our natural environment, affects our lives in many ways. In general, buildings tend to be judged on the extent to which they are functionally efficient and aesthetically pleasing, and successful buildings will have their useful life maximised because they are appreciated and cared for. To these two established criteria for evaluating a building's performance and popularity - function and aesthetics - we now need to add a third, that of overall environmental impact.

In order to facilitate closer examination, we can separate construction related environmental impacts into four main areas: energy, materials, land and water.

1.1 Energy

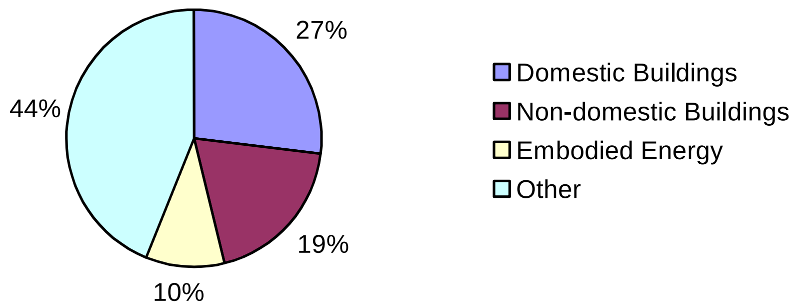
Buildings are major consumers of energy, and therefore major contributors to atmospheric pollution and climate change. In particular, the primarily fossil fuel based energy that is used to provide heat, light and power in our buildings is a major source of CO_2 emissions. There is no doubt that reducing energy use in buildings will help to cut carbon emissions and help the government meet its target of a 20 percent reduction on 1990 levels by 2010.

Figure 1: UK rate of energy consumption by final users, by sector 1965 - 2010 [1]



The building stock in the UK is responsible for 46 percent of the nation's total energy consumption, and for a similar proportion of CO_2 emissions. Domestic buildings alone account for 27 percent, as shown in Figure 2, and a corresponding level of emissions.

Figure 2: Proportions of national energy use



There is a great deal of scope to reduce the energy consumption of existing buildings, through energy conservation measures such as insulation and draught-proofing, and the use of energy efficient appliances. In new buildings, the potential is there to reduce energy consumption to near zero. Throughout Europe and North America, scores of buildings have already made the claim to be 'zero energy' through the use of super-insulation, passive solar design, renewable energy supply, air tightness, and natural daylighting and ventilation.

Unfortunately, the potential is rarely translated into reality. The amount of energy used by domestic appliances has more than doubled between 1970 and 1997. Even though appliances have become more efficient, we are simply using more of them, and newly built houses in the UK are still 3-4 times less efficient than new housing built in Germany, Canada, Sweden or Norway.

1.2 Building Materials and Construction Waste

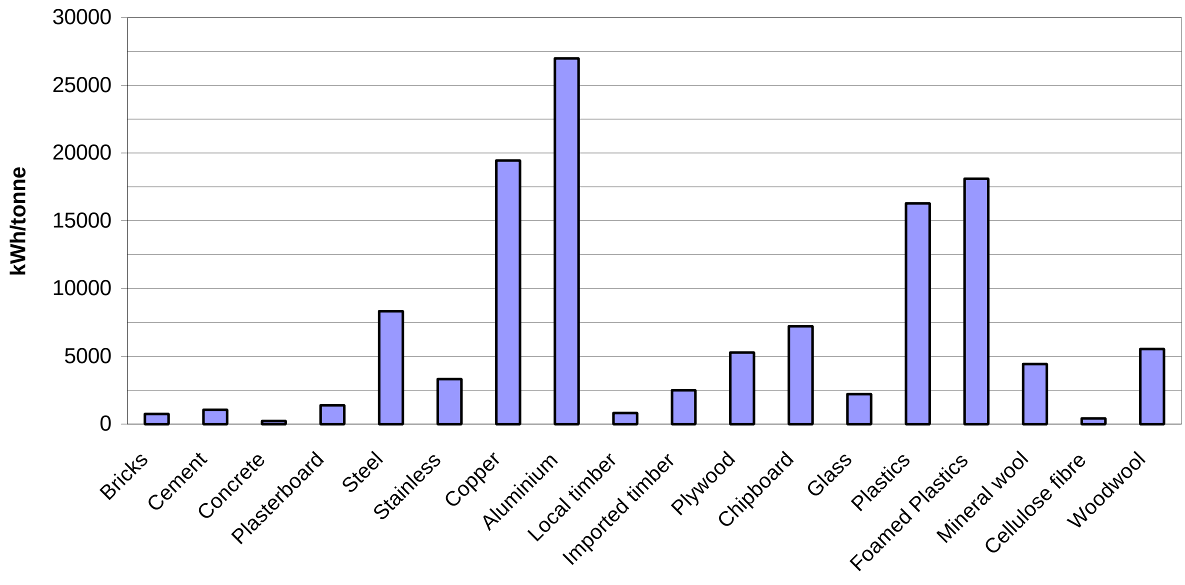
Resource use

Most construction materials are made from non-renewable resources, and account for 50 percent of all raw materials used in the UK, the equivalent of 6 tons per person per year. In the UK, the quarrying of 250-300 million tons of material each year for aggregate, cement and bricks, imposes significant environmental costs at a local level. On a global level, the mining of metallic ores in many developing countries, largely for export, results in impacts from exploration, surveying, mining, and spoil disposal, which those societies are often ill-equipped to regulate. Some resources, such as lead and zinc ores, as well as oil and gas, have very limited reserves remaining.

Embodied energy

Another energy 'cost' of buildings is the embodied energy of the materials used in the actual construction (see Figure 3). This includes the primary energy cost of gaining the raw materials, manufacture and processing, transportation at all stages, installation and maintenance over the life of the building, and finally disposal. Recent 'eco-schemes' have achieved 60-70 percent reductions on average embodied energy levels.

Figure 3: Embodied energy of common building materials, compiled by the author. Figures are taken from various sources including BRE, CIRIA, Bjorn Berge and Pat Borer.



Pollution

Manufacturing processes cause pollution to the soil, watercourses, or the atmosphere. Where these pollutants are particularly toxic or persistent, they will be harmful to present or future generations, and to animals, birds and aquatic life. The Environment Agency has reported an increase in the number of serious pollution incidents [2], with the biggest rise in water pollution. Atmospheric pollution by carbon (monoxide and dioxide), acidic gases, heavy metals and organo-chlorines can be directly attributed to the construction industry.

Waste

Construction and Demolition (C&D) waste accounts for 35-40 percent of the nation's total waste generation, amounting to 72 million tons per year. This is about four times the rate of household waste production, which is the focus of so much attention. Only 4 percent of C&D waste is recycled to higher-grade uses; the majority is simply dumped as landfill. By contrast, the Netherlands achieves a recycling rate for C&D waste of more than 90 percent, achieved at least partly by the following measures: [3]

- Since 1997, the Dutch have banned landfill disposal for recyclable and combustible components of C&D waste.
- Landfill Tax in the Netherlands was first introduced in 1996. The tariff for combustible waste is set at the same level, or higher, than the rate for incineration.
- The Dutch government is looking at enforcing an obligation to sort C&D waste at building and demolition sites.

An increase in the use of recycled and 'secondary' materials would cut the rate at which we use primary resources, and reduce the amount of waste to be disposed of. Secondary materials are mostly by-products from unrelated industrial processing, such as electricity generation or steel production, and may be used as replacements for cement or gypsum. It is important to take into consideration however, that these materials may pose a health risk where they contain pollutants from the original processing. [4] The government has set targets for increasing the amount of secondary materials used in the construction industry, and these have been met for 2002.

Table 1: Government targets for increasing use of secondary materials based on 1997 levels [5]

Target date	Increased amount	Increased percentage
By 2002	40 MT	18 percent
By 2006	55 MT	25 percent

Health

Recent concern about indoor pollutants is largely due to the fact that the air tightness of buildings has greatly improved in the last 50 years for energy efficiency reasons, so internal pollutants are not vented away so easily. There has also been a massive increase in the number of synthetic surfaces, finishes and furnishings in common use - all likely to outgas VOCs and other chemical compounds. The human health impact of this is a complex area lacking a great deal of hard information. It seems prudent however to avoid the following:

- Plastic and other synthetic finishes
- Materials with a high VOC (volatile organic compound) content
- Chemical timber treatments
- High concentrations of radon

- Known toxins such as lead and asbestos
- Relative humidity levels below 40 percent or above 65 percent

Environmental assessment

All of the considerations mentioned so far need to be taken into account when choosing or specifying a construction material. The process is the same whether the item in question is a pot of paint or a structural frame. Some impacts may be judged to be more important than others - a process known as 'weighting'. Some negative impacts may be offset by other positive impacts of the same material. For example, the high embodied energy of metals can be offset to a degree by their capacity for being recycled indefinitely.

For many individuals and small developers, any assessment is a subjective decision that takes into account a range of factors. It should ideally be based on as much objective information as possible.

1.3 Land Use

The UK government has identified a need for an extra 4-5 million new dwellings by 2016. Even with the targeted 60 percent of new developments being built on brownfield sites, the pressure to open up ever greater areas of greenfield land for development is enormous. The conversion of hitherto undeveloped land to construction use tends to be an irreversible process, and our remaining eco-systems are already under threat from the demands of agriculture and forestry, as well as urban and suburban expansion, and the growing reality of climate change.

From a wider perspective, the amount of land needed to support a modern complex city - to provide all necessary food, materials and energy, and to absorb waste - is many times greater than the amount of land covered by its roads and buildings. The 'ecological footprint' of each Londoner today is 3 times the global per capita 'share' of the Earth's resources and London itself has an eco-footprint of 293 times its geographical area. [6]

Clearly, there will be less direct pressure on greenbelts and open countryside if more brownfield and (sub)urban infill sites can be used for new housing. Unfortunately the costs of 'site remediation' or treatment of contaminated soil often makes brownfield development uneconomic. The economic incentive for continual expansion is in direct contrast to a more resource-efficient approach to urban land use and the creation of building space.

For development to be sustainable, we have to build to higher densities than the current average level of 25 dwellings per hectare (2001 figures [7]). The recently (2001) revised Planning Policy Guidance (PPG) 3: Housing [8] recommends densities of between 30 and 50 dwellings per hectare for new housing located 'in and around existing centres and other areas with good transport availability'. The Deputy Prime Minister said publicly at the Urban Summit 2002 in Birmingham that he would intervene where planning permission is to be granted to developers building in the South East at less than 30 dwellings per hectare. The Campaign for the Protection of Rural England (CPRE) welcomed this statement, but regretted that it did not extend to the whole of the UK. [9]

Eco-Footprints

The 'eco-footprint' is a measure of the amount of land we need to produce all of the materials and resources that we consume, and to absorb all of our wastes. The amount of usable land in the world, divided by the human world population gives a current per capita global share of around 2 hectares.

Other studies [10] have shown that densities of 80+ dwellings per hectare are necessary to trigger the infrastructural provision of shops, schools and public transport that are necessary to facilitate community growth and cohesion. Higher densities do not necessarily mean cramped or unattractive living conditions. Indeed, Georgian three to four-storey terraced developments equate to roughly 350-500 *people* per hectare. One new eco-development in South London, BedZED, has a density of 100 dwellings per hectare, yet every unit has good solar access and a small garden/patio.

Land for transport accounts for up to 20 percent of urban areas. In planning terms, road capacity often influences development locations, and parking provision dictates density. The provision of car-free areas and restrictions on private car ownership allow significant increases to be achieved in housing density without overall loss of amenity, as at BedZED.

1.4 Water

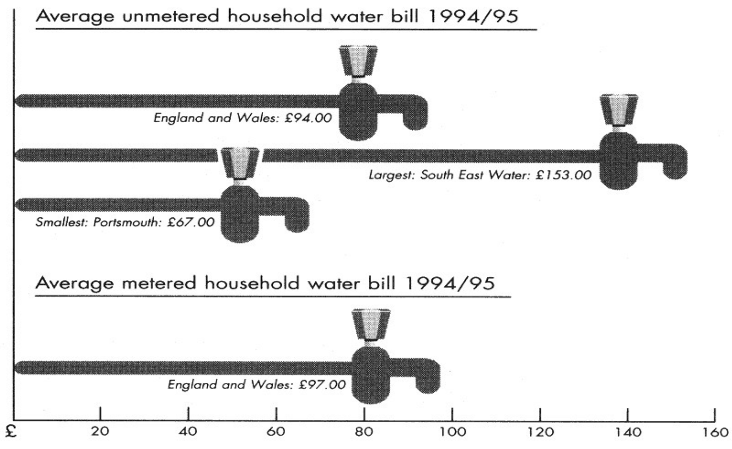
Water seems like a renewable and abundant resource but this is not always the case. Two thirds of the UK's water supply comes from surface water, which is replenished by rainfall, but one third comes from the groundwater contained in limestone and sandstone aquifers, and this is generally being extracted faster than it is being replaced.

All of our mains water supply is of drinking water quality and so we are given little option but to use highly treated water for tasks such as toilet flushing or car washing, which do not require high quality water. Water treatment is an energy intensive process that uses chemicals such as aluminium and chlorine to remove contaminants, particularly from surface water. Yet only 10 percent of the water we use is consumed for drinking or cooking.

Reducing water use would help conserve the groundwater reserves, reduce the threat to rivers caused by over-abstraction, decrease the energy demand for purifying and transporting water, and improve the effectiveness of sewage treatment. Water conservation is by far the cheapest option for handling the growing nationwide demand for drinkable water. Simple techniques in the home, such as fitting showers (not power models), spray taps and low flush (2-4 litres) WC cisterns, can radically reduce the demand for tap water. Butts for collecting rainwater can provide a suitable supply for the garden and car washing.

With the technology now available to build zero-energy houses, it is likely that water bills will soon exceed fuel bills. The real incentive to conserve the resource will be the promise of reduced costs, and so all new dwellings are now fitted with water meters, and existing customers can opt to have a metered supply, as shown in Figure 4. It is estimated that where metering has been introduced, water consumption has fallen by 10-20 percent.

Figure 4: Comparison of metered and un-metered water use rates [11]



1.5 The Environmental Imperative

In the light of government commitments to reduce carbon emissions, abolish fuel poverty and improve the efficiency of the construction industry, it is clear that a 'Business as Usual' scenario is no longer an option (see Section 3). While the importance of securing the cooperation of the industry is recognised, which can act as a restraining and conservative influence, the arguments for energy and resource efficient construction are gaining ground. Although there will undoubtedly be some dragging of feet, it is no longer a question of if, but of when and how these arguments are taken up and applied to mainstream practice.

There are certain areas relating to energy efficiency, environmental pollution and human health impacts that are already covered by legislation. Construction practice is largely governed by instruments such as the Building Regulations, the Control Of Substances Hazardous to Health (COSHH) and other Health and Safety requirements, as well as bodies such as the Environment Agency. Recent fiscal measures have sought to reduce the amount of waste going to landfill, and the amount of virgin resource extraction. These restrictions or improvements on common practice (according to your point of view) will inevitably increase, but they will only ever set minimum standards. Over and above these, every builder, developer and client has to arrive at his or her own particular equation of a) the ideal, b) the acceptable and c) the intolerable, for any given situation. The solution we end up with will have been influenced by cost, availability and convenience, and how we balance these factors against the likely environmental impacts.

The key issue here is how to give sufficient weight to the factor of 'environmental impact', such that it has a chance of outweighing other determining factors where necessary. It is important to try and establish a connection in the public mind between the impacts of construction and environmental degradation, just as people have now generally accepted (if not acted upon) the links between private transport and atmospheric pollution. Statutory and fiscal measures can help to set (and raise) 'minimum standards' to encourage improvement, but best practice will always exceed these.

1.5.1 Criteria for Sustainable Construction

The most common definition of sustainable development is that of the 1987 UN Environment Commission, under Gro Harlam Brundtland: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". [12]

The consequences of the Brundtland report have been enormous. With this definition, "the old emphasis upon environmental resources, especially energy conservation, has been superseded by a wider framework. The Brundtland Commission argued that economic and social systems could not be divorced from the carrying capacity of the environment" [Ibid]. This wider perspective on development insisted on the necessity of sustainable economic progress (rather than relentless growth) and social cohesion and inclusion as the basis for political stability. Known as the 'triple bottom line' of economic, social and environmental sustainability, this thinking has guided subsequent policy documents and legislation.

The Commission also pointed to the unsustainable inequity inherent in differential access to global resources, and the accompanying deprivation: "Poverty reduces people's capacity to use resources in a sustainable manner. It intensifies pressure on the environment". [Ibid]

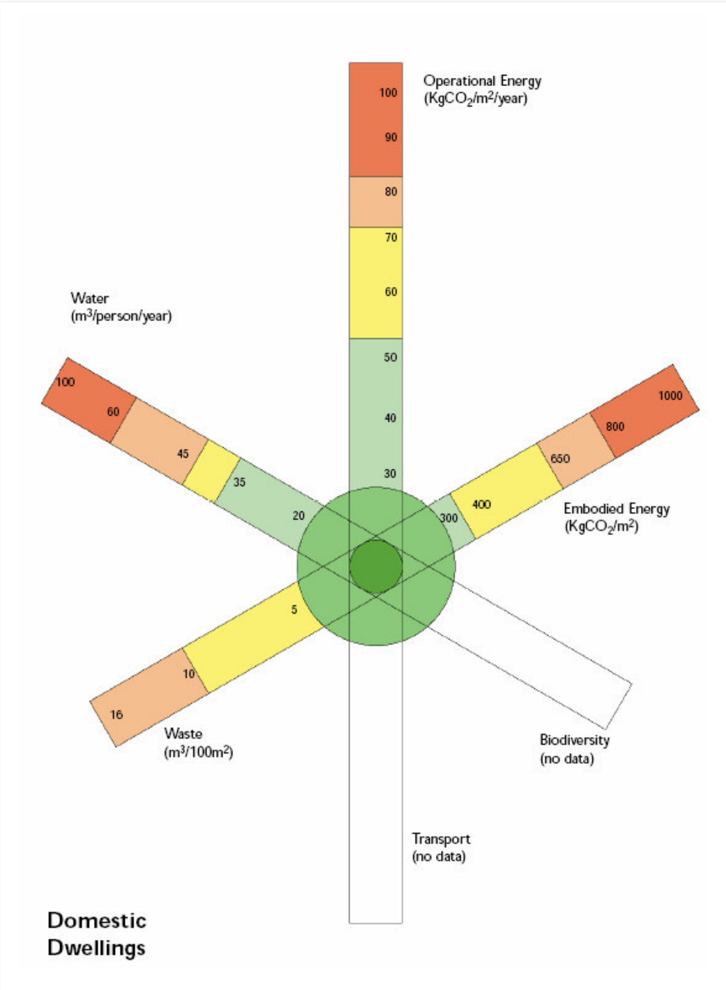
Definitions related directly to construction have sprung up in the wake of Brundtland. The Building Services Research and Information Association (BSRIA) has defined sustainable construction as "the creation and management of healthy buildings based upon resource efficient and ecological principles". [13] Norman Foster and Partners define sustainable buildings as being "energy efficient, healthy, comfortable, flexible in use and designed for long life". [Ibid]

While these general principles are useful in determining a frame of reference, more specific and rigorous criteria need to be constructed, to ease the passage from theory to practice. One definition has been developed by Rab Bennetts, chair of the Movement for Innovation (M4i) Sustainability Working Group [14], and is based on a set of six Environmental Performance Indicators (EPIs):

- Operational CO_2 emissions
- Embodied CO_2
- Water - amount used in construction
- Waste generated in construction (measured in $m^3/100m^2$ floor area)
- Biodiversity - of flora and fauna onsite, and the avoidance of pollution
- Transport - of materials and people

The working group has produced charts showing benchmarks for each construction type. Figure 5 shows the chart for dwellings. The green shading represents the best scoring 25 percent on each of the parameters; the red shading represents the worst 25 percent.

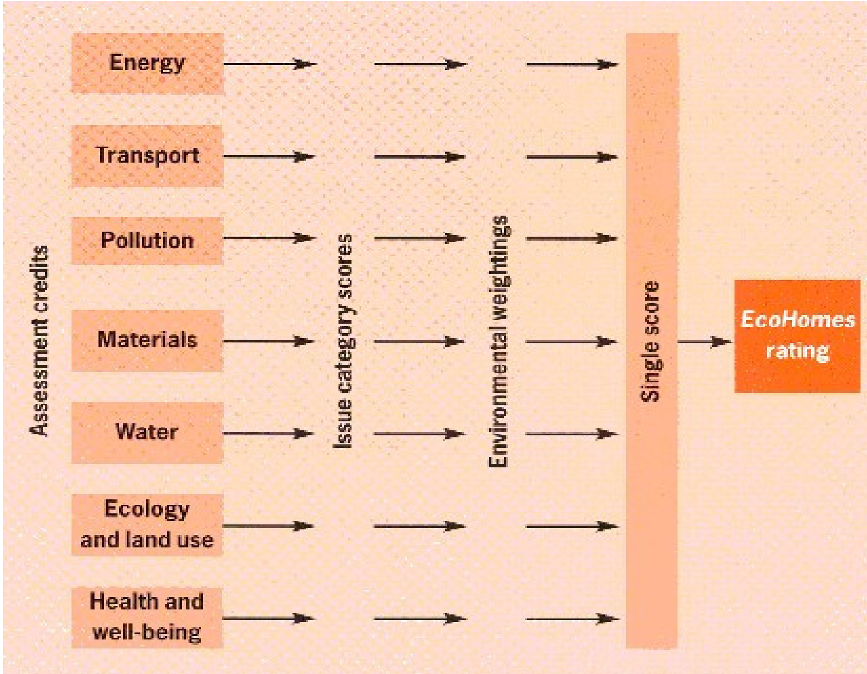
Figure 5: Chart showing the M4i sustainable performance benchmarks for dwellings



There are a number of environmental assessment methods for designers, developers and clients to use in evaluating sustainability in construction. They are all based on Life Cycle Assessment (LCA) methodology, which identifies material, energy and waste flows throughout the manufacturing and construction process, and over the lifetime of the building.

The one most used in the UK for domestic buildings is the BRE's 'Eco-Homes' rating [15], which is based on their 'Green Guide to Specification' [16]. Buildings are judged against the seven environmental impacts identified in Figure 6. Performance on each of these criteria attracts a score, which then has weightings applied to arrive at a final score. These weightings, which represent judgements on the relative importance of the environmental impacts, were the result of an in-depth consultation exercise undertaken with government, academics, industry and environmental groups. Overall scores range from 'Pass' (75 marks out of a possible 207, which represents the minimum performance that all developments should reach) through to 'Excellent' (145 marks out of 207, indicating 'exemplary performance across the full range of issues').

Figure 6: Illustration of the process of calculating the EcoHomes rating [16]



In addition, there are a number of energy auditing systems, such as the Government's Standard Assessment Procedure (SAP) Energy Rating, which must be calculated and produced for all new dwellings and buildings undergoing conversion to become dwellings. This estimates total annual energy use, cost and likely CO_2 emissions, and gives a score between 1 (poor) and 120 (excellent). The average score for the existing UK housing stock is between 40 and 50. While there is no obligation to reach a particular score, a rating of 80-85 (depending on floor area) could be used to demonstrate compliance with the Building Regulations. Calculation of the Carbon Index, one of the three ways of demonstrating compliance with the Building Regulations, uses the same methodology and data as SAP (1998 version), and has a score of 0-10 (the higher the better). The SAP procedure assumes a standard occupancy based on floor area, standard heating patterns and average UK climate, for reasons of national comparison.

The National Home Energy Rating (NHER) assesses energy efficiency rather than just energy use, and is based on total fuel costs per square metre to achieve an adequate overall temperature. This is a voluntary scheme, which has been used by developers to demonstrate the energy efficiency of their buildings, and by various Local Authorities to help compile local house condition surveys, as required by the Home Energy Conservation Act (HECA). A more advanced version of the basic NHER assessment will calculate the effectiveness and cost savings of various energy efficiency measures.

The Centre for Alternative Technology (CAT) uses a fairly broad and eclectic, but perhaps less measurable, definition of sustainability [17]. This definition states that buildings should:

- be responsive to the local climate
- provide a healthy and comfortable internal environment
- have low energy requirements and therefore low running costs
- be constructed with low-energy, sustainably produced materials
- specify reused, recycled and/or recyclable materials
- be prudent in its use of non-renewable resources, including water
- be designed and sited so as to minimise reliance on private transport
- be durable and designed to last at least 100 years

In particular, CAT advocates a holistic approach to any definition or discussion of sustainable building. 'That is to say, it must take as wide a perspective as possible and foster an understanding of the complex interrelationships between different kinds of impact'. [Ibid]

References

[1] Royal Commission for Environmental Pollution (RCEP), *Energy - The Changing Climate,* London, RCEP, June 2001

[2] The Environment Agency, *Spotlight on Business Environmental Performance,* Bristol, The Environment Agency, 2002

[3] Sustainable Building Magazine, 1-2002, p22

[4] Toxic ash from municipal incinerators in London has been widely distributed to the building trade for use in breezeblocks and roads, *The Guardian*, 5 July 2001

[5] Department of Environment, Transport and Regions (DETR), *Making Waste Work,* London, DETR, 1995

[6] www.citylimitslondon.com, accessed 29/10/04

[7] Department of Transport and Local Regions (DTLR), *Land Use Change in England: Residential Development to 2001*, London, DTLR, 2001

[8] Department of Environment, Transport and Regions (DETR), *Planning Policy Guidance Note 3: Housing*, London, The Stationary Office, 2000

[9] Campaign for the Protection of Rural England (CPRE), *Stop Sprawl*, Building for a Future magazine, 2002, Volume 12, No. 3, p6

[10] McLaren, Bullock & Yousuf, *Tomorrow's World*, London, Earthscan Publications, 1998

[11] Stauffer, J. *Safe to Drink,* Machynlleth, Centre for Alternative Technology, 1996

[12] Bruntland, G. (ed.), *Our common future: The World Commission on Environment and Development*", Oxford, Oxford University Press, 1987

[13] Brian Edwards, *Rough Guide to Sustainability,* London, RIBA Publications, 2001

[14] The Movement for Innovation (M4i), *Environmental Performance Indicators for Sustainable Construction: Sustainability Working Group Report,* London, 2001

[15] Rao S et al, *Eco-Homes*, Watford, BRE Publications, 2000

[16] Anderson, J. and Howard, N. *Green Guide to Housing Specification*, BRE Publications, 2000

[17] Borer, P. & Harris, C. *The Whole House Book*, Machynlleth, Centre for Alternative Technology Publications, 1998