MATERIALS

The use of basic construction materials such as concrete, steel, timber and glass has profound impacts on both the local and global environment, particularly through the consumption of non-renewable natural resources, and the production of climate-changing carbon dioxide. Therefore, the materials specified for construction and uses in a building greatly affect its long-term sustainability.

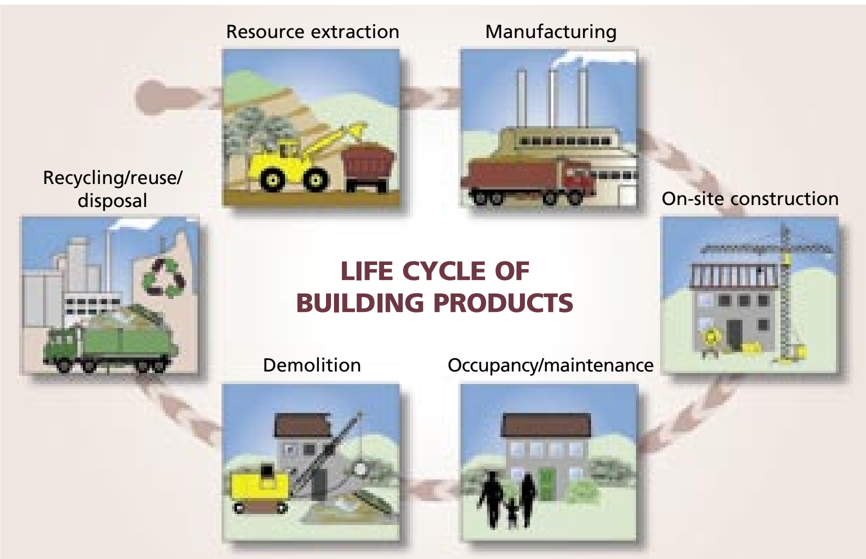
Importantly, a small number of materials account for most of the energy consumption and hence CO_2 production of our built environment. For a typical house, approximately 75% of the total energy consumed in producing building materials is for concrete, plasterboard, bricks and mortar. Glass, steel, copper and paint account for 13%, and timber 8%. While there remains significant debate over the environmental merits of various materials, there are now some clear means of analysis and comparison. As always in construction, each project is different, thus the focus should be to select appropriate materials for a development rather than identifying absolute ideals. Suitable materials will satisfy the requirements of design, availability, cost and sustainability considerations.

This chapter aims to provide the information designers need to enable them to specify the most sustainable materials possible, whether for new projects or for refurbishments. It also considers the important issue of how materials arising from deconstruction and demolition can be re-used or recycled in the most sustainable way.

LIFE CYCLE ASSESSMENT (LCA)

Sustainable practice considers the future implications of decisions made in the present. When selecting materials for construction therefore, this needs to involve an assessment of a material's impacts from the extraction of raw material, through manufacture, construction, use, maintenance, demolition and disposal. Life Cycle Assessment (LCA) is generally considered the most comprehensive method of dealing with these issues. There are many different ways of carrying out LCA, and care must be taken that its objectivity is not influenced by any vested interests in its outcome. To meet this challenge, the BRE worked with the DETR to develop a set of objective guidelines for LCA of building materials and components. This has provided a useful publication called 'Environmental Profiles of Construction Materials, Components and Buildings' and a database of LCA information that is available on the Internet.

Most significant materials specification choices are made at the sketch design stage. To inform decisions at this stage, information needs to be available for the unit area of each element e.g. 1m^2 of wall, ceiling etc. This approach is used by the 'Green Guide to Specification' which scores different specifications with A, B or C ratings (where A is very good). The use of A and B rated elements from the book provides credits in the BREEAM assessment for offices and the new EcoHomes Award.



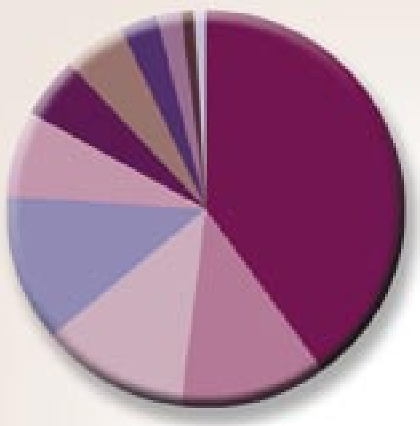
Information about the materials themselves is obviously not enough: the designer must also take into account the building performance in terms of water used, energy consumed and waste generated. An initial software design tool called 'Envest' has been developed to explore the major early design trade-offs, for example between the impact of insulation and the energy saved by insulating. To make the complex consideration of environmental matters in conjunction with materials selection easier, the information needs to be presented in a simple form. This has been done using 'Ecopoints', a single life cycle score. This score is based on LCA and has used a consensus approach to determine the relative importance of different issues. Ecopoints are used to show the relative impact of different design choices in the Envest system.

It is important not to confuse LCA with whole life costing (WLC). WLC focuses solely on the economic consequences of certain design options, whereas LCA has been designed to assess the environmental impacts of design options. A joint LCA/WLC approach can be very useful and has already been used in a number of new developments. It should be remembered that LCA is still at the development stage – any such information must be presented in a way that it cannot be used out of context by building professionals and their clients.

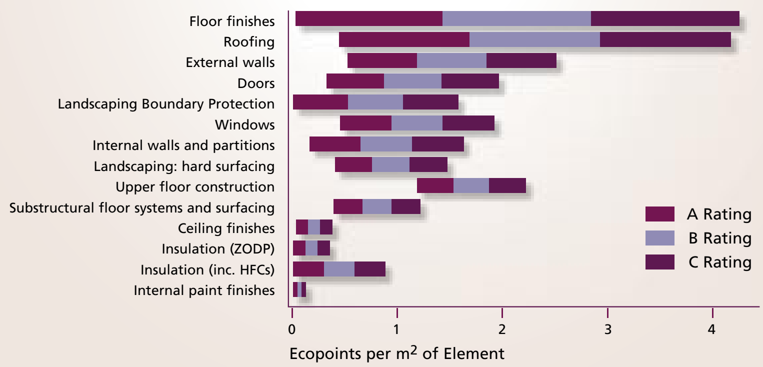
The pie chart below shows the relative contribution of a building's elements to a typical building's environmental impact. The chart below shows the range of Ecopoints/m^2 likely for each element. The lower the Ecopoints value, the more sustainable the solution is likely to be.

Useful though these analysis tools are, it is important that designers do not place too much store by them, and it is suggested that they use them only as one element of a comprehensive approach to specifying materials. With sensible use, however, techniques such as LCA can be used by designers to help them towards their goal of sustainable construction.

Contribution of building elements to typical building impact



Summary Rating ABC ranges for different elements



CRITERIA FOR MATERIALS SPECIFICATION

Some detailed guidance on the selection of specific materials is provided in the Materials Comparison charts at the end of this chapter. However, since materials technology is continually developing, it is important that anyone responsible for specifying materials understands the main criteria for materials selection from the sustainability point of view, so that they can apply these to any new materials which become available. The information about existing materials also needs to be reviewed continuously; for example, a material, which was previously considered safe for human health, may emerge as a long-term health hazard, or the availability of a material may change due to external political or commercial pressures. Designers must therefore keep up-to-date with any new information and legislation that may influence choice of materials. The major issues which need considering each time a material is specified are summarised below.

Embodied Energy

- Insist that manufacturers provide environmental impact information and check against independent sources where possible (e.g. BRE's Environmental Profiles Database).
- Consider the transport, recycling/reuse factors (use locally derived products where possible).
- Use more recycled and reclaimed products that have relatively low embodied energy.
- Minimise the use of highly processed, embodied energy-intensive products.

Toxicity & Emissions

- Avoid any materials known or suspected of being toxic (these are highlighted in the Materials Selection tables presented below).
- Always use safer alternatives where these are available and technically feasible.

Biodiversity

- Ensure that materials have low biodiversity impact.
- Ensure that materials have a low impact on soil quality and/or microclimate.

Renewable Materials

- Use as much renewable, raw material as possible in preference to non renewable.
- Minimise the use of non-renewable materials.

Durability/Recycling/Waste

- Use robust, removable materials.
- Specify small, easily-handled components.
- Use removable fixings such as bolts, screws and clips rather than complex mechanical fasteners.
- Use homogeneous rather than composite materials.
- Use layered instead of glued components.

MAJOR TYPES OF MATERIALS USED IN CONSTRUCTION

This section summarises the main considerations that need to be given to the principle materials currently used in construction. More details about these and other materials can be found in the Materials Comparison tables.

Wood

Wood is often seen as one of the most environmentally friendly materials: it is clearly a renewable resource and some of it can be sourced locally. In the UK, however about 90% of timber is imported from Northern Europe and the USA, which means that a lot of energy is required for its transportation. Wide scale forestry can also impact very negatively on the environment, for example by reducing CO_2 absorption and destroying habitats for flora and fauna. International certification schemes (such as the Forest Stewardship Council mark shown below) provide independent confirmation that forests are being well managed with assessment using internationally recognised standards. A chain of custody certificate guarantees that the forest materials used to manufacture the product come from a well managed forest. CEC policy specifies that only FSC labelled or certified alternative timber should be used in construction.

FSC Trademark© 1996 Forest Stewardship Council A.C. FSC-GBR-570

Natural Power Building, Dumfries. Designed by Organic Buildings, Inverness.

Any preservation methods used for timber need to be considered since they can be very toxic. The accuracy of the information provided for these is not always high, so the minimum levels should always be specified.

In practical terms, designers should bear in mind that wood is really only suitable for timber frame buildings up to five storeys high. For anything taller, steel or masonry construction is a better option.

Concrete

Concrete is a very versatile material that can provide some important sustainable properties for buildings. It has been used to good effect in the BRE Environmental Building where the floor/ceiling construction combines thermal mass, ventilation path and acoustic insulation. The key ingredients of concrete are cement, water and aggregate (sand and gravel, or crushed rock). Cement for concrete accounts for about 3% of the UK's CO_2 emissions and has a relatively high embodied energy cost. Recent research indicates that there are no embodied energy/CO_2 differences between reinforced concrete construction and the main alternative construction method using structural steel. Designers should ensure that they research materials for each project carefully and that they set out clearly the reasons for specifying particular materials. They should always consider the use of more sustainable forms of concrete which use recycled aggregates and which replace some of the cement content with materials such as pulverised fuel ash (PFA), a waste product of coal burning power stations. Research is underway to look at the possibility of recycling materials such as ground brick dust as a cement substitute.

Metals

Although the embodied energy content of metals is high, this can still be acceptable when metals are clearly the most suitable material for the job. This is certainly the case at present for the frames of tall buildings and for cables that conduct electricity. Metals can be recycled which can substantially reduce their embodied energy, for example recycled commercial aluminium has an energy content that is about one quarter less than that of primary aluminium although it should be mill finished. There are often more sustainable alternatives to metal in common building applications. For example, using FSC durable timber or fibre cement is more sustainable than using composite steel panels for cladding. More detailed examples are provided in the Materials Comparison tables.

Glass

Glass is a material with a promising future in sustainable development. It has a relatively low embodied energy, which can be offset by its ability to provide passive solar gain. For example, the embodied energy in $1m^2$ of south-facing glazing is recovered in about one week by passive solar gain (refer to the Building Energy and Design chapter for more details). It also provides a good way of introducing natural light into buildings, and lowers the requirement for artificial lighting. Glass can also be used to incorporate photovoltaic units for energy production, a use that will undoubtedly become more widespread in the future. The most sustainable forms of glazing should be used, i.e. double glazing, or argon-filled low emissivity glazing instead of single glazing. One disadvantage of glazing however is its high cost, which means it needs to be used strategically in order to maximise its potential sustainable benefits. Glass has been used to good environmental and aesthetic effect in the new Scottish Parliament Building.

MATERIALS TO AVOID

Any materials that are known to cause damage to either human health or to the environment must be avoided. These include any materials with known toxic or carcinogenic effects and ozone-depleting chemicals such as CFC's and HCFC's. Any tropical hardwoods from non-sustainable sources should also be avoided. In planting schemes, peat should be replaced with suitable alternatives to avoid environmental damage at the point of extraction. There is currently an important debate taking place about the impact of chlorine on the environment. In the built environment, two examples of the use of chlorine are UPVC windows and PVC sewers. Designers should look at the more sustainable alternatives such as FSC durable timber for windows, and vitrified clay sewers. More detailed examples of materials to avoid are provided in the Materials Comparison tables.

MAINTENANCE CONSIDERATIONS

Maintenance considerations should form an integral part of the design of any building, and long term plans should be in place which take into account the known life-span of the various materials used, including plans to upgrade materials to more sustainable options when they become available. Maintenance, building operation and housekeeping do not usually involve the replacement of large volumes of building materials. However, the way maintenance and housekeeping is done will influence the need to replace materials. Lengthening replacement intervals will potentially have an environmental impact by reducing resource consumption.
Any renovation or addition presents an opportunity to make environmentally sound material selections. The same criteria apply, as discussed in the design section, when seeking alternative lower environmental impact replacement materials. Unfortunately, the most sustainable materials are not always the easiest to maintain – for example external timber frame windows need more regular attention that PVC – but the importance of sustainability considerations should not be ignored in favour of easy maintenance. Material Safety Data Sheets (MSDS) and information on cleaning and pest-control methods should be included in building environmental services and housekeeping policies and procedures. Any paints, varnishes, fillers and other materials used for general maintenance should be specified on the basis of their impact on human health and the environment. These and other materials should be compared with the aid of information such as the Materials Comparison charts presented at the end of the chapter. However, such information will date very quickly, so maintenance staff should try to keep their knowledge up-to-date, by regularly reviewing recent relevant information.
All techniques and hardware used for any repairs should try to use removable and re-usable fittings where possible – e.g. use non-ferrous screws rather than ferrous nails. This will make any future required maintenance both quicker and easier, and will also reduce the waste at the end of the building's life by allowing for greater re-use/recycling of its component materials (see the next section).

CONSTRUCTION MATERIALS WASTE

From the very early stages of the project those involved should consider the opportunities for re-using and recycling construction and demolition (C&D) waste both on and off-site. Any refurbishment projects should be viewed not only as an opportunity to upgrade materials used to more sustainable options, but also as an opportunity to recycle or to re-use any redundant materials. The same principle applies to any deconstruction or demolition work – obviously the more of the waste material that can be recycled or re-used, the lower the transport costs for its removal, as well as any Landfill

Tax costs incurred for its disposal. In the year 2000, 41% of Scotland's construction waste ended up in landfill sites. It is estimated that of this, 37% was potentially recyclable, (Priority Waste Stream Project: Construction & Demolition). Designers must try to make materials choices that will help to reduce this unsustainable level of waste and its associated costs.

Designing out C&D Waste

Much of the waste that ends up in landfill sites arises through poor design and specification at the start of a project. For example, the widespread use of rapid-setting, high strength Portland cement mortars over the last 60 years has made the reclamation of attached bricks and blocks very difficult. Designers must therefore think very seriously at the design stage about specifying materials that can be re-used (e.g. use layered components, not glued; use screws not nails), and should think about designing in recycling facilities on site.

Demolition

Wholesale demolition of buildings is to be avoided where possible, since it can result in the waste of many valuable materials and components. It is often used because it is a far quicker process than deconstruction, and is seen as a more cost effective way of disposing of unwanted materials, especially where there are time pressures to commence work on a new development on the cleared site. If demolition is still the preferred operation, the contractor should nevertheless be encouraged to adopt a selective approach and to remove the most valuable or potentially contaminating materials and fittings safely and intact for later use and re-processing before the demolition proper commences. This approach was adopted following the fire in Cowgate, Edinburgh. For safety reasons it was decided to demolish the affected buildings as soon as possible, but this only started after the Category C Listed archways at the front of the Gilded Balloon had been saved.

Standard Life building, Edinburgh.

DECONSTRUCTION

Deconstruction is the process of dismantling a structure in the reverse order to which it was constructed. It is critical that sufficient time is given for deconstruction – if there is inadequate time, there will be no time to dismantle re-usable materials and they may end up being wasted. Plans should be drawn up to focus on each material during deconstruction and to separate the materials for re-use, recycling and disposal at the time they are removed.

The section below provides a brief summary of which common building elements can be deconstructed, the order in which they should be handled, and how they should be treated. A fuller account of the deconstruction process itself, including Health and Safety issues are provided in 'Designing for Dismantling; and 'Building deconstruction: Re-Use & Recycling of Building Materials' which are referenced at the end of this chapter. Using the approach below, there should be less than 10% of non re-usable waste remaining at the end of a building deconstruction.

ORDER	ELEMENT	DECONSTRUCTION APPROACH
1	Extensions	Remove these first as entire units since they otherwise interfere with the removal of one type of material or of whole sections of the original structure. Once removed, their elements can be deconstructed, material-by-material, in the reverse order of their construction.
2	Roof Tiles & Slates	Clay tiles and natural slates can usually be re-used. Concrete tiles can be crushed and used in recycled aggregate. The cost of reclaiming roofing materials may increase by the need to provide safe access using scaffolding to the reclamation level. Many breakages of slates and tiles that occur during reclamation can be avoided by specifying the use of non-ferrous fittings (such as copper or aluminium nails).
3	Steel Sections	UBs, RSJs, Channels and Angles can be disassembled using mobile cranes, trained riggers and slingers. The specification of simple bolted connections makes it far easier to deconstruct. Designers should always consider alternative methods of fire protection to encasing steel in concrete, since this makes it far more difficult to reclaim the steel. Designers should also avoid filling steel girders with holes for services, or welding on complicated bracket structures, and should use mechanical fixings or something similar.
4	Structural Timber	Structural timber is nearly always re-useable. Lift down the large roof trusses intact with a crane, and then guarding against progressive collapse, disassemble the trusses into smaller sections on the ground.
5	Soft Stripping of Building	This should be carried out in two separate stages. First strip out all valuable or re-usable fittings such as hardwoods, panelling features, light fittings, non-ferrous plumbing systems, high value switchgear and plant room contents etc. Next remove everything else, sorting everything at ground level. Unless covered with laminates, all timber is recyclable. Carpets, underlays, ceilings and floor tiles, plasterboard and fibreglass cannot currently be recycled in the UK and will usually need to be disposed of via landfill.
6	Windows	Try to remove the windows intact, separating the glass and frame at ground level, and recycling the components. Timber and glass can be recycled – there are only limited possibilities for recycling PVC, although it can be used in small proportions as a constituent of low grade recycled PVCs.
7	Timber Floors and Joists	Care needs to be taken as many older buildings have been found to be effectively held up only by the floor joists. These should be progressively stripped out using mainly hand tools.
8	Masonry Walls	Bricks should be handles as little as possible; to avoid breakages and should usually be sorted and cleaned on site.
9	Concrete Cladding Panels	These can be more easily removed if lifting eyes have not been grouted up during construction. A rubber grommet or similar should be specified instead.
10	Metallic Cladding	This can commonly be re-used in the agricultural sector.

ORDER	ELEMENT	DECONSTRUCTION APPROACH
11	Steel Frame Buildings	These can either be disassembled for use as whole sections, or can be sheared down for scrap metal ready for the smelter.
12	Concrete Frame Buildings	The concrete frame can be pulverised and processed into secondary aggregates.
13	Concrete Floor Slabs and Foundations	These can be processed into secondary aggregates.
14	Pile Foundations	Too difficult and expensive to remove, so usually best left in situ. These may be re-usable if the original building's specifications are still known.

INFLUENCING SUSTAINABLE MATERIALS SELECTION

The increasing costs associated with landfill are probably most likely to influence a move towards the use of more sustainable materials, and their efficient re-use or recycling at the end of their construction life. In some parts of the EU there are far greater restrictions on the types of material that can be disposed of via landfill. For example, in Denmark, any waste that can be recycled or burnt (for energy recovery) is banned from landfill, and there is a graduated waste tax that is highest for landfill. Construction and demolition waste must be separated into separate fractions at source, in order that as much as possible may be recycled. Such policies have resulted in Denmark managing to recycle over 90% of its C&D waste. If these types of policies and legislation were introduced in the UK, this could have a major and immediate impact on materials choice.

Materials selection is a very complicated area with several contributing factors. The development of objective methods of assessment and environmental rating schemes both nationally and internationally will help to provide an objective basis for materials comparison, and so may help to influence a change towards the greater specification of more sustainable materials. A side effect of such schemes is that they are often used to provide data that can be used as a marketing tool to help promote developments on an environmental basis. This may serve to raise the profile of sustainable materials in terms of public awareness, but, unless it originates from a reliable source, the data itself should usually be treated with a degree of caution.

FUTURE DEVELOPMENTS

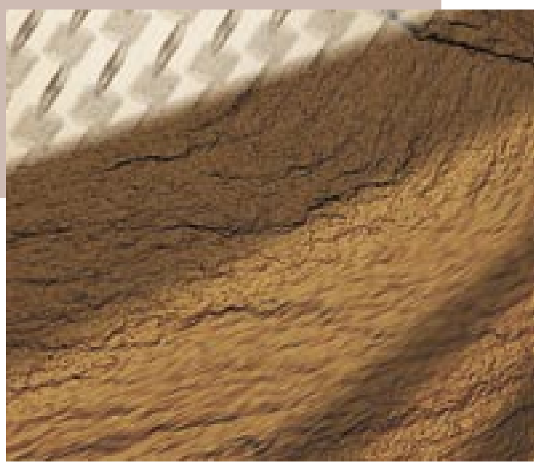
All building designs should include strategies for upgrading in the future, and this should include provision to incorporate more sustainable materials as they become available. A number of useful materials and techniques which are either available now, or will soon be available are:

- aerogels (sometimes referred to as solid smoke) – ultralight materials that are about 99% air and are highly effective insulators;
- paints that change their thermal properties, for example becoming more reflective, at higher temperatures;
- translucent concrete that will allow us to think differently about light and structure;
- insulating concrete – concrete with enhanced thermal insulation properties;
- glazing that reflects light towards the ceiling and back into a room to make better use of daylighting;
- greater recycling –crushed glass may be used as a concrete aggregate;
- new, more efficient photovoltaic materials (both silicon and non-silicon-based);
- more efficient lighting including broad-spectrum light-emitting diodes;
- new and more efficient storage materials for energy and for hydrogen.

Other materials, which may be available in the more distant future, are:

- materials, from insulation to concrete to glazing that combine intelligence elements (sensors, controls and communication devices) to report and change status, for example to reduce energy consumption;
- biologically based plastics – in the future we may be able to 'grow' everything, from plastic bags to translucent sheets.

The European Union, under its Construction Products Directive and European Eco-label scheme, is seeking increased transparency and consistency in the environmental claims about products. Already products such as household appliances, hard floor coverings, paints and varnishes and light bulbs are covered by labelling requirements. This is likely to be significantly extended in the future. More restrictive legislation in terms of what can be incinerated and disposed of in landfill sites will also promote a move towards the specification and use of more sustainable materials.



MATERIALS SPECIFICATION CHARTS

Floor Structure

Ground/Intermediate Floor construction, Screeds & Floor Coverings

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Ground floor	FSC timber (suspended floors)/hollow ceramic elements	a third	• solid concrete with primary aggregate	• N/A
	hollow concrete elements with recycled aggregate	half		
	solid concrete with reclaimed aggregate	some saving		
Ground floor thermal insulation	mineral wool/expanded polystyrene	saving/slight extra	• extruded polystyrene	• N/A
	foamed glass	extra	• polyurethane	• isocyanate extremely harmful to human health, hazardous additives
	perlite/vermiculite	extra/double		
Party/ intermediate floors	FSC timber	a third	• solid concrete with primary aggregate	• N/A
	hollow ceramic & concrete elements with RCA/limestone	half		
	solid concrete with RCA	saving		
Floor/ceiling acoustic insulation	coconut fibreboard	3 x cheapest	• N/A	• N/A
	flax felt strips/rolls	small extra		
	natural wool felt	little above cheapest		
	wood fibre boards	cheapest		
	recycled natural rubber and cork	dearest		
Balconies	FSC durable timber	half/small extra	• concrete with primary aggregate	• N/A
	sectional steel/aluminium	a quarter/saving	• non-FSC tropical timber	
	prefab concrete with RCA	half/extra cost		
Floor screeds	flue-gas gypsum anhydrite	half	• phosphogypsum anhydrite	• phosphorous radioactive/carcinogenic
	natural gypsum anhydrite	extra cost		
	sand-cement	savings		
Bath/WC floors	granitic/terrazzo	significant extra	• PVC (vinyl tiles)	• phthalates/suspected hormone disrupter
	ceramic tiles	significant extra		
	polyester	significant extra		
Floor coverings	cork floor tiles	same/saving/saving	• vinyl (PVC)	• phthalates/suspected hormone disrupter
	linoleum with natural fibre backing	extra/extra/half	• synthetic carpets	• styrene/carcinogenic
	sisal & coir carpet with natural backing	same/saving/saving	• woolmark carpets with synthetic latex backing	• pyrethoids/nerve poison & styrene/carcinogenic
	maize, rush & seagrass matting	same/saving/saving		
	untreated wool carpet with jute, natural latex or wool backing	extra/extra/same		
	untreated wool & nylon carpet with natural backing	extra/same/saving		
	tongue & groove softwood flooring	saving		
	ceramic tiles	double/double/saving		
	FSC hardwood strips	extra/extra/extra		
	quarry stone tiles	extra/extra/extra		

Foundations to below floor level

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Foundation posts	FSC timber with concrete top	cheaper	• concrete with primary aggregate	• N/A
	concrete with reclaimed aggregate	cheaper		
Ground below suspended floor	shells	extra	• PVC membrane	• plasticisers/carcinogenic
	formed concrete/stud	half		
	expanded clay granules/polyethylene membrane	a quarter more		
Damp-proof membrane	low odour chemical DPC	additional cost	• chemical solvent DPC	• organic compounds/ nausea,
	polyethylene DPC/DPM	no difference	• bitumous DPC/DPM	• nervous system/ headaches
	engineering brick slate/thin steel sheeting	substantial extra		

Wall Structure

External Cavity Wall Construction

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
External wall skin	sustainable durable timber	significant extra/ significant extra	• Non FSC tropical timber	• N/A
	loam construction	extra/extra	• Preserved softwood	• preservative toxins (phenols copper, chrome, arsenic)/cause nausea, nervous system, headaches
	masonry brick/block	little difference/saving		
	fibre-cement	same/saving		
	resin-bonded plywood	extra/same		
Internal wall skin	FSC timber elements	savings	• concrete	• N/A
	sand-lime blocks	savings		
	flue-gas gypsum blocks	half		
	cellular concrete blocks	extra		
	natural gypsum blocks	savings		
Cavity wall insulation	cork board	little/no difference	• polyurethane	• toxic ingredients
	cellulose (recycled paper)	significant savings	• extruded polystyrene	• hazardous additives
	mineral/ rock wool	extra cost		
	expanded polystyrene	savings		
	glasswool/foamed glass	savings		
Cladding	FSC durable timber/compressed unfired	significant extra/	• non-FSC tropical timber	• N/A
	clay brick	double/extra	• composite steel panels	• N/A
	sustainable plywood	extra/extra/saving	• composite aluminium panels	
	fibre cement	same/small extra/saving		
	recycled profile steel or aluminium	savings		
External wall rendering	ceramic tiles	3 x cheapest	• N/A	• N/A
	mineral render	cheapest		
	synthetic render	4 x cheapest		

Internal Wall Construction, Wall & Ceiling Systems

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Party walls	earth-based (loam)	half	• solid concrete with primary aggregate	• N/A
	FSC timber frame	small saving		
	brick (sand-line)	1/8th		
	cellular concrete block	–		
	porous brick	–		
	concrete with RCA	savings		
	limestone	savings		
Solid walls	earth-based (loam)	1/25th	• pre-cast concrete elements	• N/A
	flue-gas gypsum block	1/15th		
	brick (sand-lime)	1/12th		
	cellular concrete block	1/5th		
	natural gypsum block	1/13th		
Plasterwork	flue-gas gypsum	–	• phosphogypsum	• phosphorous/radioactive
	lime-mortar	same		
	natural gypsum	significant savings		
Wall & ceiling frame systems	softwood	little or no difference	• N/A	• N/A
	steel	substantially more		
	aluminium	extra cost		
Wall & ceiling panelling systems	karite medium board	extra cost	• phosphogypsum board	• phosphorous/radioactive
	flue-gas gypsum board	little or no difference	• medium density fibreboard (MDF)	• formaldehyde
	natural gypsum (plasterboard)	little or no difference		
	formaldehyde-free MDF	extra cost		

Glazing, Windows and Doors Systems

Glazing

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Glazing type	argon-filled low emissivity	significant extra	• single	• N/A
	air-filled low emissivity	significant extra		
	double	extra		
Installation	dry	cheapest	• N/A	• N/A
	semi-dry	same as cheapest		
	wet	dearest		

Window frames and doors

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
External window/door frames	FSC durable timber	little extra/same	• non-FSC tropical timber • uPVC	• N/A • vinyl chloride/ carcinogenic & phthalates, suspected hormone disrupter
	untreated softwood	extra / saving		
	softwood with solid borate implant	significant extra/ significant extra		
	sustainable plywood (door)	significant extra/ significant extra		
	aluminium	expensive		
	preserved softwood	significant extra		
	recycled uPVC	significant extra		
External window sills	ceramic	1.8 x cheapest	• N/A	• N/A
	concrete	cheapest		
	natural stone	very expensive		
	prefab. concrete	cheapest		
	cast stone	3 x cheapest		
	synthetic stone	3 x cheapest		
	aluminium	2.5 x cheapest		
	fibre conc.	2 x cheapest		
Internal window frames	FSC timber	little extra	• non-FSC tropical timber	• N/A
	galvanised & coated steel	significant extra		
Internal window sills	ceramic tiles	4 x cheapest	• N/A	• N/A
	natural stone	very expensive		
	softwood	5 x cheapest		
	sustainable plywood	3 x cheapest		
	cast stone	8 x cheapest		
	fibre cement	2.5 x cheapest		
	chipboard	cheapest		
	synthetic stone	8 x cheapest		
Internal doors	honeycomb with hardboard skins	extra cost	• non-FSC tropical timber	• N/A
	European softwood	double		
	sustainable plywood	3 x		
	chipboard	extra cost		
Internal door thresholds	FSC durable wood	extra cost	• non-FSC tropical timber	• N/A
	sustainable softwood	little/no difference		
	steel with coating	extra cost		

Roof Structure

Roof construction & coverings

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Roof shape	pitched	lowest	• N/A	• N/A
	arched	extra		
	flat	slightly more		
Pitched roof construction	sustainable FSC timber	significant extra	• plywood from non-FSC tropical wood	• N/A
	box panels/sustainable plywood	extra cost		
	chipboard (low formaldehyde)	significant savings		
	chipboard	significant savings		
Pitched roof insulation	cork/cellulose/sheep's wool	extra/saving	• polyurethane /polyisocyanurate	• isocyanate extremely harmful to human health
	flax	unknown		
	mineral wool/expanded polystyrene	extra/saving	• extruded polystyrene	
Pitched roof covering	green turf/timber shingles/reed	saving	• zinc	• hazardous additives
	clay or concrete roof tiles	–	• copper	• toxic to water organisms
	fibre-cement slates/corrugated panels	–		
	bitumous slates	–		
Flat roof construction	softwood rafters & joinery	significant savings	• concrete without reclaimed aggregate	• N/A
	steel sheets/cellular concrete	–		
	concrete with reclaimed aggregate	significant savings		
Flat roof insulation	cork	same/saving	• polyurethane /polyisocyanurate	• isocyanate extremely harmful to human health
	expanded heavy duty polystyrene/dense mineral wool	saving/extra	• extruded polystyrene	• extruded polystyrene
	foamed glass	saving		
	perlite	saving/extra		
Flat roof covering	green 'sedum'(turf)	extra	• zinc	• toxic to water organisms
	EPDM sheet/natural rubber	half/small extra	• PVC	• plasticisers/carcinogenic & phthalates /suspected hormone disrupter
	modified bitumen felt	half/small extra		
	blown bitumen felt/EPD with bitumen layer	saving/extra		
	recycled PVC stainless steel, aluminium /copper /zinc sheet	a third/small/extra same/extra/extra		
Flashings	polyethylene membrane	1/6th/half	• lead	• lead/nervous system
	EPDM membrane	savings/double	• zinc	• toxic to water organisms
	polyisobuten (PIB) with Al, gas	small saving/double		

Plumbing & Internal Waste

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Water supply piping	polyethylene (cold water use only)	saving	• lead	• lead/nervous system
	polybutylene/polypropylene	saving		
	stainless steel	saving		
	copper	saving		
Internal waste	ceramic	extra	• PVC	• plasticisers/carcinogenic & phthalates / suspected hormone disrupter
	polypropylene/polyethylene	savings		
	recycled PVC	extra		

Heating Installation (for highly-insulated buildings)

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Individual space heating	gas wall heaters	small extra	• N/A	• N/A
	low wattage electric heaters (wall-mounted)	cheaper		
Central space/water heating	correctly sized solar & condensing boilers	extra cost	• standard oversized boiler • standard combi-boiler or electric water heater	• NOx/respiratory problems
	condensing combination boiler	extra cost		
	high efficiency combination boiler	extra cost		

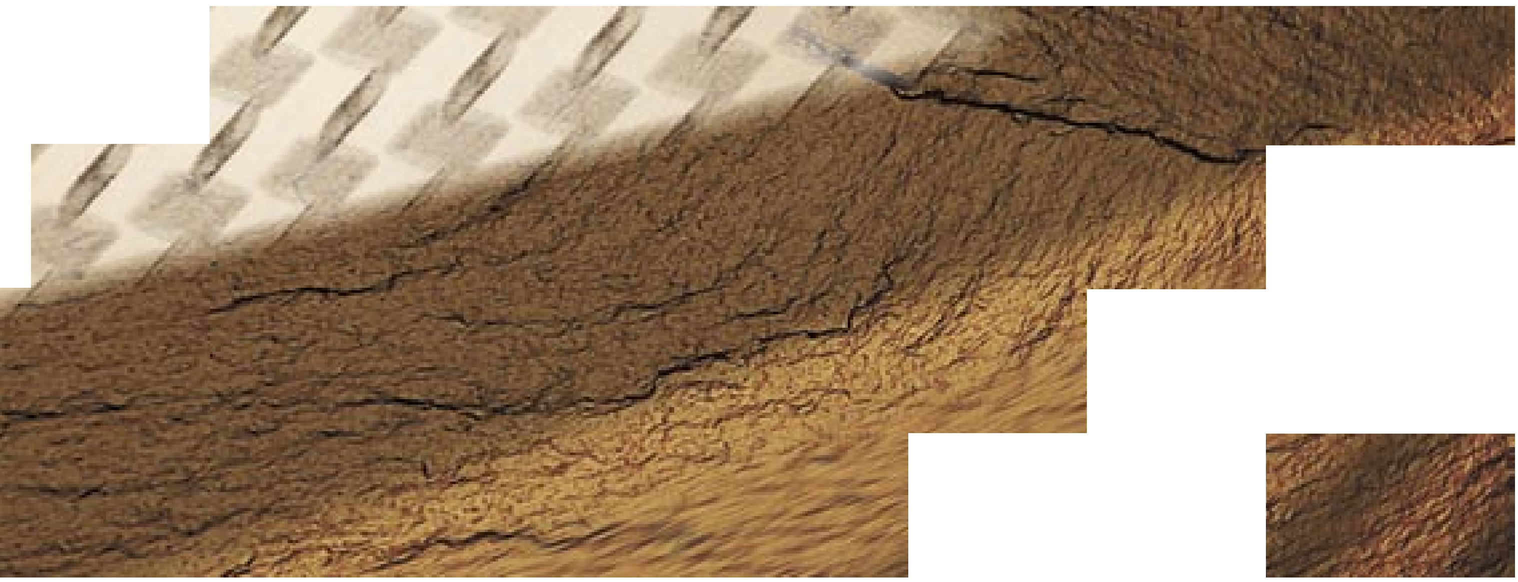
External

Drainage, gutters and downpipes

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Sewers	vitrified clay	extra cost	• PVC	• vinyl chlorides & phthalates/carcinogenic & suspected hormone disrupter
	polyethylene (PE)/polypropylene (PP)	savings		
	concrete	3 x		
	recycled PVC	double		
Gutters	FSC timber	extra/saving/extra	• PVC	• as above
	polyester/coated galvanised steel	4x/2x/6x	• zinc	• toxic to water organisms
	coated aluminium/recycled PVC	2x/extra/4x	• copper	• toxic to water organisms
Lining	EPDM/modified bitumen	half/7x/8x	• PVC	• as above
	blown bitumen	half/7x/8x	• zinc	• as above
	polyester	fifth/tenth/eleventh	• copper	• nervous system
Drainpipes	PE/PP	half/fifth	• PVC	• as above
	polyester	same/half	• copper	• as above
	steel/recycled PVC	extra/saving		

Landscaping

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Hard paving	recycled aggregate concrete slabs	extra/savings	• asphalt	• N/A
	concrete slabs	same/saving	• in-situ concrete	• N/A
	turf	extra/saving		
	brick pavers	3x saving		
	concrete blocks	extra saving		
	granite setts	extra/saving		
Semi-hard paving	wood/bark chippings	same	• gravel	• N/A
	recycled glass/sand	9x		
	shells/river pebbles	extra		
Garden barriers	hedges	savings	• recycled PVC	• N/A
	woven wood waste	same	• non-FSC tropical timber	• organic solvents/nervous system, headaches, nausea
	untreated softwood on concrete spur posts	extra cost	• copper chrome arsenate (CCA) treated timber	
Privacy screens	hedges	savings	• non-FSC tropical timber	• N/A
	sustainable FSC timber with concrete footing	savings	• copper chrome arsenate (CCA) treated timber	• organic solvents/nervous system, headaches, nausea
	masonry	extra costs		
Bin stores	FSC durable timber	extra cost	• non-FSC tropical timber	• N/A
	untreated softwood on concrete spur posts	little or no difference	• copper chrome arsenate (CCA) treated timber	• organic solvents/nervous system, headaches, nausea
	masonry/prefab concrete	extra cost		
	recycled PVC	little or no difference		



Paint Finishes

Element	Sustainable choices in order of preference	Cost of sustainable option/s relative to non-sustainable	Less sustainable option	Toxicity/Health effects of Non-sustainable option
Interior painting (wood)	natural wax	small extra	• alkyd (oil-based) paint	• organic solvents/nausea, headaches, nervous system/reproductive effects
	water based natural stain	small extra		
	water-borne acrylic (gloss)	extra cost		
	water-borne alkyd	savings		
	natural paint	small extra		
	high-solids alkyd	small extra		
Exterior painting (wood)	natural paint	small extra	• alkyd (oil-based) paint	• organic solvents/nausea, headaches, nervous system/reproductive effects
	boiled paint	small extra		
	high solids alkyd	small extra		
	water-borne alkyd	savings		
	water borne acrylic (gloss)	extra cost		
Wall surface preparation	none	N/A	• solvent-based preservative	• benzene/reproductive effects
	natural preservative	7 x		
	water borne preservative	small extra		
Interior painting (walls)	whitewash	savings	• alkyd (oil-based) paint	• organic solvents/nausea, headaches, nervous system/reproductive effects
	linseed oil emulsion	extra cost		
	mineral paint	expensive		
	water-borne natural stain	small extra		
	natural paint	savings		
	water borne acrylic emulsion	extra cost		
Exterior painting (wall)	mineral paint	expensive	• alkyd (oil-based) paint	• organic solvents/nausea, headaches, nervous system/reproductive effects
	water-borne natural stain	small extra		
	natural paint	savings		
	water borne acrylic paint	extra cost		
Ferrous metal painting	natural paint	extra cost	• lead red lead • epoxyl alkyd paint • thermal galvanising	• lead/nervous systems • harmful emissions to workers
	duplex galvanising	expensive		
	high solids alkyl	small extra		
	alkyd (oil-based) paint	same		
	iron red lead	saving		

REFERENCES

- http://www.barbour-index.co.uk/content/home/
- Barbour Index
- Building Research Establishment

For details of Materials Information Exchange, Green specifications of materials and other information see

- http://www.bre.co.uk/

For Environmental Information from the Building Standards Institute see

- http://www.bsi-global.com/Building/index.xalter
- Confederation of Building Industry http://www.cbi.org.uk/home.html
- http://www.cepmc.org/index2.htm
- European Producers of Construction Materials

For details of the Construction ExcellenceProgramme see

- http://www.constructingexcellence.org.uk/
- http://www.dti.gov.uk/sectors_building.html
- Dti Construction
- http://www.hsedirect.com/
- Heath and Safety Executive

10. LAWS, POLICIES AND GUIDELINES

For information on material selections to mitigate climate change see

- http://www.iigcc.org/docs/PDF/Public/ConstructionSector_2004.pdf
- http://www.environment-agency.gov.uk/commondata/105385/ea_sustainable_908180.pdf

Environment Agency

- http://www.environment-agency.gov.uk/netregs/sectors/364906/364921/?version=1&sectorid=364906
  Net Regs

11. USEFUL CONTACTS

- Association for Environment Concious Building: http://www.aecb.net/
- CAT, Centre for Alternative Technology, UK: http://www.cat.org.uk
- Gale and Snowden: http://www.ecodesign.co.uk
- Timber Frame Company Ltd: http://www.thetimberframe.co.uk
- The Ecological Building Network - lots of very useful material on ecological building: http://www.ecobuildnetwork.org/
- OIKOS: http://www.oikos.com/
- Environmental Building News (USA): http://www.ebuild.com/index.html
- The Hockerton Housing Project: a first - an earth sheltered autonomous housing development (i.e. CO_2 neutral, all energy and resources harvested and managed on site, etc.) in Nottinghamshire: http://www.hockerton.demon.co.uk
- The Living Villages Trust: a company and Trust that undertakes ecological housing developments for sale, with a first scheme in Shropshire (UK): http://www.livingvillage.com
- Building and Social Housing Foundation: http://www.bshf.org/
- SALVO recycled building materials and products market: http://www.salvo.co.uk/mags/EcoDesign.htm
- South Somerset District Council Sustainable Construction Project: http://www.southsomerset.gov.uk
- The Housing Forum (A response to the Egan Report Rethinking Construction commissioned by the DETR): http://www.thehousingforum.org.uk/
- Construction Resources Exhibition Centre and products supplying: http://www.ecoconstruct.com/
- TRADA: http://www.tradatechnology.co.uk
- Walter Segal Self Build Trust: http://www.segalselfbuild.co.uk/
- Centre for Sustainable Construction, Building Research Establishment: http://www.bre.co.uk/sustainable/index.html
- BRECSU at the Building Research Establishment (energy conservation in buildings): http://www.bre.co.uk/brecsu/index.html
- The Zero Energy Development (ZED) project at Beddington, in the London of Borough of Sutton: http://www.zedfactory.com

SUSTAINABLE MATERIALS CHECKLIST

The following checklist is a guide to some of the items that should be considered in sustainable design. It is not comprehensive. Clients and designers should use the checklist PRIOR to the start of each project and agree on the issues to be incorporated. Some of the items may be easily 'ticked off', while others are more of a prompt to consider further action. In each case however, the checklist should be used electronically with the 'Action' columns completed providing explanations as to why a particular item was not relevant or included in the project.

GENERAL ITEMS

Item no	Checklist Action	Action confirmed
1	Liaise with all relevant other council staff as well as the client before commencing any work.	

LIFE CYCLE ASSESSMENT

Item no	Checklist Action	Action confirmed
1	Assess the environmental impact of all materials from extraction to disposal using a technique such as Life Cycle Assessment.	
2	Familiarise yourself with the BRE 'Green Guide to Specification' rating system.	
3	Take into account overall building performance in terms of water used, energy consumed and waste generated (using Ecopoints, for example).	
4	Consider using Whole Life Cycle analysis in conjunction with Life Cycle Assessment.	

MATERIALS SPECIFICATION CRITERIA

Item no	Checklist Action	Action confirmed
1	Ensure that all timber specified is FSC accredited or an alternative relevant accreditation.	
2	Insist that manufacturers provide environmental impact information and check against independent sources where possible (e.g. BRE's Environmental Profiles Database).	
3	Consider the transport, recycling/reuse factors (use locally derived products where possible).	
4	Use more recycled and reclaimed products which have relatively low embodied energy.	
5	Minimise the use of highly processed, embodied energy-intensive products.	
6	Always use safer alternatives where these are available and technically feasible.	
7	Ensure that materials have low biodiversity impact.	
8	Minimise the use of non-renewable materials.	
9	Use robust, removable materials	
10	Specify small, easily-handled components	
11	Use removable fixings such as bolts, screws and clips rather than complex mechanical fasteners	
12	Use homogeneous rather than composite materials	
13	Use layered instead of glued components.	

MATERIALS TO AVOID

Item no	Checklist Action	Action confirmed
1	Avoid any materials which are known to be harmful to human health or to the environment.	
2	Avoid the use of PVC.	
3	Avoid the use of non FSC approved timber.	
4	Avoid the use of any materials containing phosphorous, such as phosphogypsum.	
5	Avoid the use of any materials containing isocyanates, such as polyurethane.	
6	Avoid the use of any materials containing, lead, zinc or copper.	
7	Avoid oil-based paints.	
8	Avoid oil-based preservatives.	
9	Avoid any wood treated with Copper Chrome Arsenic (CCA) preservative.	
10	Avoid the use of chemical Damp Proof Courses.	
11	Avoid the use of non formaldehyde-free MDF.	

MAINTENANCE CONSIDERATIONS

Item no	Checklist Action	Action confirmed
1	Consider maintenance in terms of the building or development's entire life cycle.	
2	Put long term maintenance plans in place at the at the start of a project design.	
3	Always design for maintenance which requires the least materials, transport, energy and subsequent waste.	
4	For refurbishments, replace any unsustainable materials with more sustainable ones wherever possible.	
5	Use removable and re-usable fittings where possible.	
6	Only use materials for maintenance and cleaning which are not known to harm human health or the environment.	
7	Ensure that data and instructions are available for all materials used for maintenance.	

DEMOLITION/DECONSTRUCTION

Item no	Checklist Action	Action confirmed
1	Avoid wholesale demolition, deconstructing instead where possible.	
2	If demolition is deemed necessary, try to remove potentially harmful materials first.	
3	If demolition is deemed necessary, try to re-use the most valuable elements.	
4	Deconstruct buildings in the reverse manner to which they were built.	
5	Sort and separate all materials on site.	
6	Re-use or recycle as many materials as possible (refer to the Deconstruction Chart in this chapter for more details)	

INFLUENCING SUSTAINABLE MATERIALS SELECTION

Item no	Checklist Action	Action confirmed
1	Separate construction and demolition waste at source to encourage re-use and recycling.	
2	Consider landfill as the last resort.	
3	Involve building occupants in achieving higher recycling and re-use targets, and ensure that they are provided with positive feedback.	
4	Ensure you are aware with environmental rating schemes and use them to specify the most sustainable materials.	

FUTURE DEVELOPMENTS

Item no	Checklist Action	Action confirmed
1	Design buildings so that they have the maximum possible future materials upgrade potential (e.g. use easily removable components, layer materials instead of glueing them etc.).	
2	Consider using aerogels as insulators.	
3	Consider using paints that change their thermal properties.	
4	Consider using translucent concrete.	
5	Consider using insulating concrete.	
6	Consider using glazing to reflect light up to the ceiling then back into the room to maximise daylight.	
7	Consider using concrete with recycled glass as an aggregate.	
8	Consider using photovoltaic materials.	
9	Use the most efficient types of lighting currently available, including broad spectrum LEDs.	
10	Use the most efficient types of storage materials currently available for energy and hydrogen.