

SUSTAINABLE OFFICE DESIGN

UNLOCKING PERFORMANCE & PRODUCTIVITY

Sustainable design is an exciting area of architecture and building which is moving into the mainstream. And there's a good reason that 'green' or sustainable buildings are also known as 'high performance buildings': they not only tend to save on running costs, there is also growing evidence that they can increase productivity and well-being for occupants through improved lighting and air quality.

By Beatrice K. Otto

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Where office buildings have been designed or refurbished to be more sustainable, productivity gains in terms of better quality of work and reduced absenteeism can often dwarf the reductions in energy bills. Refits which are more sustainable can therefore yield faster returns on investment than is commonly expected.

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SUSTAINABLE DESIGN & BUILDINGS

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SUSTAINABLE DESIGN & BUILDINGS

WHAT'S IT ALL ABOUT?

“Technology and the growth of computers allows you a much freer palette as an architect. Also, the study of nature and the way plants grow is more and more available. Bring these things together and there is quite a strong human response. Combine with a better understanding of materials, then we are in for a much richer phase of architecture.”

Nick Grimshaw

People & planet

Sustainable design creates products, places, processes and systems which optimise human well-being now and in the future without compromising the well-being of the planet.

Architecture is one of the most exciting, visible and burgeoning areas for sustainable design with a rich array of techniques, systems, technologies and materials already in place that can drastically reduce the effects buildings have on the environment while bringing about a step change in comfort and efficiency. Buildings can be self sufficient in energy, purifying their own air, and treating at least some of their own waste.

Performance & productivity

Sustainable office design can deliver higher performance in energy and other resource use, and higher productivity in human terms. People simply work, see and think better in offices that have more natural lighting, fresher and cleaner air, and where they have more control over their immediate lighting or temperature levels. At a practical level, it simultaneously minimises the:

- number
- amount
- volume
- weight
- toxicity
- and use of materials, energy and water

while maximising the use of materials, energy and other components that are:

- clean and safe
- renewable
- easy to repair, reuse, recycle or refurbish
- and benign towards the environment

FIRST PRINCIPLES

Health, wealth and happiness

Optimising well-being involves thinking about the personal, physical, social, cultural and economic effects of buildings. Hospitals can consider the curative effects of light, colour, and air quality on human health and spirit. Residential and public buildings can reduce crime and social isolation or disaffection. Schools can improve the concentration and commitment of pupils by responding to their human needs. Workplaces can enhance productivity by designing with occupants in mind.

Slow the flow

Currently, materials tend to flow down a one-way street. We extract, process, use, throw away. Most things we use (including buildings) come with serious baggage in energy, materials and emissions. By using materials that have been reclaimed or recycled, and by designing for durability and adaptability (the two go hand in hand), we can slow the flow, ideally to a trickle.

Reduce the use

Water, energy, materials, components. Find ways to lighten your footprint and lightweight materials. For example, you could use a lighter material, or consider lightweight structures that retain strength but reduce material density: particleboard with a honeycomb structure has a high strength to weight ratio: metal can be produced in a foam structure rather than a solid state.

“We can reduce our energy use by 80 percent with no reduction in our quality of life.”

Paul Hawken,
author of *The Ecology of Commerce*

Loop the loop

Conventional life cycle analysis looks at ‘cradle to grave’ (extraction to disposal), but this is shifting towards closed loop thinking, what McDonough Braungart Design Chemistry (MBDC) calls ‘cradle to cradle’. This includes renewable materials or energy, such as plastics based on plants rather than petroleum (bioplastics or biopolymers), or materials that are easily recycled: recycled aluminium uses 95% less energy than the virgin stuff.

From product to performance

Total financial benefits of green buildings are over 10 times the average initial investment required. Energy savings alone exceed the average increased cost of building green. The relatively large impact of productivity and health gains reflects the fact that the direct and indirect cost of employees is far larger than the cost of construction or energy. Even small changes in productivity and health translate into large financial benefits.

The Lawrence Berkeley Laboratory and Capital E Group cost benefit analysis of green building for 40 Californian government agencies (www.cap-e.com)

Sustainable design takes a step back and considers results or benefits rather than products. Most products are a means to an end; by focusing on the end, we can rethink the means. BP was an oil company until it decided that it wanted to deliver energy, of which oil is only one form. Amory Lovins, a champion of improved performance in office buildings, talks about buying 'coolth' (the opposite of warmth) instead of air-conditioners. A synonym for 'sustainable building' is 'high performance building'. Keep that in mind, it's where all sustainable design roads should converge.

Hydro Building Systems has developed TEmotion ('T' meaning 'technology' and 'Emotion' referring to the good feeling we get from elegant, integrated solutions). TEmotion is an external cladding system in aluminium and glass which contains an all-in-one package for heating, cooling, ventilation, lighting and sun-screening, creating the potential to reduce primary energy consumption by about 40%.

A properly designed workplace requires less building infrastructure, which takes up less space, produces less heat, and consumes less power than traditional workspaces – while supporting employees more effectively.

Christina Kite, Vice President

Cisco Global Work Place Resources and Enterprise Risk Management

Of systems and simplicity

Sustainable design integrates systems and functions and designs out duplicating or conflicting elements. It works best where it optimises a whole system by designing 'out' things that don't need to be there. Optimising parts of a system would mean buying a more energy-efficient air conditioner. Optimising the system would create a simplifying cascade which might look like this:

- lighting provides a large part of the demand for 'coolth'
- improve natural lighting, both in quality and quantity
- install dimmable lighting and individual controls
- reduce artificial lighting (and, incidentally, energy use)
- plant deciduous trees outside – their summer leaves prevent direct sunlight heating up the building, their winter shedding lets sun contribute heat
- reassess the demand for coolth
- install some passive ventilation systems
- now decide if you still need air conditioning; you might, but probably a great deal less than if you had upgraded existing equipment without looking at the whole system.

The master designer

Biomimicry is the study of nature applied to design and innovation. Nature has been trying things out for millennia and scientists and designers are learning how to apply these lessons from the molecular level to entire systems.

Interface's Entropy carpet came about when a designer noticed the random beauty of autumn leaves on a forest floor. This randomness was incorporated into the patterning of carpet tiles, reducing installation waste to 1%, and increasing ease of replacing tiles, while appealing aesthetically to customers.

In materials, spider silk has more tensile strength, relative to its weight, than steel; it's been said that if you expanded a spider web to the size of a fishnet, its resilience could stop a Boeing in mid-flight. FTL Studio mimics the tensile strength of spider silk in its elegant, flexible, lightweight structures, and is now beginning to embed solar cells into the fabric.

Fun with factoids

- According to the DTI, non-renewable energy consumed in building services accounts for about 50% of UK carbon dioxide emissions.
- Construction generally accounts for about 45% of the total global flow of raw materials (China produces about half the world's cement)
- Envirowise has found that as much as 10% of construction materials on sites were never used.

WHAT ARE THE BENEFITS?

PERFORMANCE & PRODUCTIVITY

"A minimal upfront investment of about two percent of construction costs typically yields life cycle savings of more than ten times the initial investment."

California Sustainable Building Task Force

“Buildings with a “green rating” command rental rates that are roughly three percent higher per square foot than otherwise identical buildings – controlling for the quality and the specific location of office buildings.”

Doing Well by Doing Good?
Green Office Buildings, 2009

The chief, tempting benefits of making your office more sustainable are:

- lower running costs due to virtuous circles of energy and material savings
- rising productivity due to happier and healthier employees

They go hand in hand though productivity gains often dwarf reductions in running costs. There is growing evidence that even where the initial costs are higher than conventional design, the payback, for example through reduced energy bills, can be fairly fast. When gains in productivity are factored in, the payback can be very fast – staff costs usually hugely outweigh energy costs, so a small gain in productivity can translate into a heftier financial gain.

In addition, there are reduced liabilities (and potential opportunities) from meeting environmental legislation, such as the Landfill Tax, Climate Change Levy or the newly launched CRC Energy Efficiency Scheme. There are government issued carrots as well as sticks, such as the Enhanced Capital Allowance Scheme which allows businesses to claim 100% first year capital allowances on investments in energy saving products or technologies.

‘The growth of green building is driven partly by energy efficiency and other cost savings but also by the need of businesses to attract the best employees. These buildings can make very attractive workplaces.’

Christine Ervin, President & CEO, US Green Building Council

HOW DO I BEGIN?

TEN TOP TIPS

Choose a champion

Sustainability is a cross-functional idea touching most key business functions, yet is quite a hazy notion to those who haven't been exposed to it. To prevent its wafting through people's minds without engaging them it needs a champion, someone who 'gets it', and has the status, authority and persuasiveness to bring people on board, such as the CEO or head of communications, for example.

Shift mindsets

Indifference to sustainable design is usually based on misperceptions that sustainability is somehow about suffering and cost. Properly done, it's quite the opposite, but whether you are the designer or the client, you may have to draw on some shining examples to demonstrate that it can improve quality of life and work.

**“Efficiency is free.
Ask for more.”**

Lee Eng Lock,
Singaporean efficiency genius

Create a dream team

Whether you're a designer or client, start with a team. Sustainable design needs a range of skills and perspectives. At a functional level, daylighting and dimming systems need great coordination to work properly, and so it makes sense to involve lighting designers, contractors, equipment manufacturers and building operators. At a business level, an office redesign is a great opportunity to invite the productivity giant in – burgeoning evidence points to leaps in well-being and productivity while drastically reducing energy and other costs. Not for nothing sustainable buildings are also called 'high performance buildings'.

Paint a picture

Sustainability, once people know what it is, is a rare beast because it can inspire them in unexpected ways. Scandia, the Swedish hotel chain, took 5,000 employees on a sustainability trip and were astounded at the effect it had in galvanising overall enthusiasm for performance improvement.

If you are the client, involve all employees in the design (or redesign) of the office. Give them a glimpse of what a sustainable office can look and feel like. There are some wonderful examples of workplaces which have fresh air, natural lighting and are a delight to work in.

Joined up thinking

See your office as a whole system, not a series of components. Integrating systems, such as lighting, heating and cooling, is key. If you consider air conditioning without looking at lighting, you will miss the chance to reduce air conditioning. Look for what shouldn't be there, as well as what should.

Think before you leap

Some 80% of costs are determined at the design and concept stage; Joseph Romm has calculated that by the time 1% of a project's costs have been spent 70% of its life cycle costs will have been committed. Thinking, planning, designing are (relatively) cheap. By spending more time in the thinking zone, you could save costly rethinking later. Think twice, what to design in: integration, synergies, multi-functionality, and what to design out: superfluity, complexity, compound inefficiencies, waste.

Measure your footprint

Look at your current ventilation and thermal control, plus lighting and energy use. Also think about the impact of work patterns – if most employees drive or use public transport, for example. Use carbon calculation tools to get a better sense of your overall environmental footprint. Reducing the footprint often means reducing costs.

'The design concept, as William McDonough puts it, had "taken the filters out of the pipes and put them where they belong – in the designers' heads". Everything that shouldn't be in the process had been eliminated by design.'

Hawkins, Lovins & Lovins
Natural Capitalism

Track your footprint

Designing an office with sparkling sustainability features may miss a trick if you don't follow through on maintenance and monitoring. Even with energy efficient systems, it has been found that more regular monitoring and tweaking of controls can yield surprising additional cost savings.

Invite ideas

Companies with internal competitions for sustainability ideas have usually reaped far more in savings and other benefits than they aimed for. Dow Chemical began an annual competition for wringing out new efficiencies that would save money and resources. They set tough criteria with short paybacks, but found that the number and quality of projects increased over time as employees got into the swing of generating and implementing ideas.

Keep it simple, stupid

People can be overwhelmed by the quantity and complexity of sustainability concepts (not to mention the jargon). Choose or create a definition that works for you and stick to it. Procter & Gamble adopted the UK Government's definition around creating quality of life for all, now and in the future, as a way to help employees engage with the concept. It was something people could relate to and act on.

WHAT SHOULD I LOOK FOR?

BASIC ELEMENTS

To design a more sustainable office, there are a few basic elements. If you are the client, ask designers and contractors to deliver on this wish list, and look at the relevant sections.

Element	Optimal	Minimal
ENERGY	use of energy efficient measures or equipment, energy saving mechanisms, devices and behaviour, and if possible renewable energy	use of energy, especially from non-renewable resources
AIR	fresh air and thermal comfort, using natural ventilation	pollution, particulates and emissions, use of mechanical air conditioning
LIGHT	individual control of lighting levels for different tasks & evenly diffused natural light	glare and shadow contrasts, use of energy intensive artificial light
WATER	use of rain or recycled water, and water saving devices	use of water
MATERIALS	use of renewable, recycled or recyclable, lightweight, durable and non-polluting materials	use of materials, particularly non-renewable, energy intensive, non-recyclable, toxic or polluting materials
FURNITURE	easily maintained, refurbished or reconfigured, using materials as above	use of high emission materials, from non-renewable resources or cannot be recycled

INTERLOCKING ELEMENTS

Bear in mind these are interlocking building blocks, with a great deal of mutual impact. An upholstery fabric big on 'outgassing' (noxious emissions) will affect air quality. More daylight will reduce the need for artificial light which will cut energy use and the demand for cooling. Some materials use or pollute a lot of water in their manufacture, and so on.



Some other things to consider:

Adaptability

In addition, an ability to reconfigure office space to meet future needs as the business evolves will reduce the necessity of major refits if the business is reorganised. This can be achieved through:

- modular furniture
- raised floors so that furniture can be moved and work stations reconnected without a spaghetti mess of wiring
- modular cooling capacity to allow for changing levels of occupancy
- refurbishment – some companies allow you to change the upholstery, or table tops, for example, extending their useful life and allowing a 'makeover' without starting from scratch
- avoiding styles that will quickly date

Dim the din

Noise can profoundly affect concentration and contentment and can be mitigated through:

- moving office equipment with its constant whirrs, hums, clicks and clunks, into a space away from people's desks by networking printing, fax and other facilities
- sound absorbing materials
- use of white sound to reduce background noise

Procter & Gamble's open plan offices in Geneva are almost silent due to the isolation of office equipment and the use of white noise. In GE Money's offices in Newcastle, copy machines are located in a central point and bespoke screens serve to reduce their noise.

Sticks and carrots

The government provides a range of incentives (and disincentives) to encourage business to become more sustainable. Examples are the CRC Energy Efficiency Scheme, the Climate Change Levy and Landfill Tax.

ENERGY

Energy efficiency improvements that use the best available technologies and practices and integrated, whole-building design approaches, can, on average, reduce consumption by 43%

U.S. National Renewable Energy Laboratory, 2007

“A 90% efficient co-generation system at the Chicago Convention Center saved \$1 million a year in energy costs and cut carbon dioxide emissions in half.”

Joseph Romm
Cool Companies

REDUCE THE USE

About 90% of the greenhouse gas emissions of standard commercial buildings come from the consumption of energy during their use. This is where the big savings are in terms of reducing their full life cycle energy use and emissions.

Energy efficient equipment

From light bulbs to printers. For example, ceiling or whole building fans can provide a temperature reduction as high as 9°F while using 10% the electricity needed for air conditioning.

Energy saving equipment

Occupancy sensors that switch off lights in empty rooms, photosensors that dim artificial lighting if not needed, and dimming systems and individual controls can all reduce energy use. In addition monitoring devices for heating and cooling systems can make a big difference to energy performance.

[Morgan Lovell's head office](#) has controls that automatically switch off audio-visual equipment when it is in standby mode. The office received the highest BREEAM rating for a project of its type in the UK.

Energy saving culture

Instill an energy saving culture so that people don't leave computers on all night. Standby mode can use more power than actual operation over the lifetime of a piece of equipment. The OECD has calculated that standby mode accounts for 5-10% of domestic electricity consumption.

Energy demand

Maximising natural light and ventilation to reduce the need for artificial lighting and cooling can lead to a huge reduction in energy use, particularly if combined with energy efficient systems.

The Deutsche Bank office in Appold Street used clever design to double the population of the building from 900 to 1,800, greatly reducing the energy consumption per head. Designing for density does not mean packing them in like sardines, it means using space intelligently. Some building projects which have much higher population densities actually look and feel more spacious... even to the occupants!

Reduce the need for heating through insulation, though more is not necessarily better. Research has shown that cavity wall insulation more than 50mm thick, and roof insulation more than 250mm thick (as required by UK regulations) doesn't yield notable decreases in fuel or emissions.

The Bow, in Calgary, has used building orientation to reduce energy consumption, facing the atrium south-southwest, rather than north.

Embodied energy

Embodied energy is the energy that went into making or transporting something. Aim to source materials, fixtures, furniture or equipment designed to reduce energy use in manufacture, or even offering carbon neutral options. Try to avoid sourcing things that have travelled four times around the world, or at least account for that when weighing up their relative impacts.

Cool Carpet is an innovation by Interface, allowing customers to buy a carbon neutral option. The programme offsets greenhouse gas emissions through projects that reduce energy use, or increase the use of renewable energy, or otherwise reduce emissions.

Renewables

Consider the installation of renewable energy sources such as solar panels or vertical wind turbines. The headquarters of Condé Nast in New York produces nearly 10% of its electricity from photovoltaic and hydrogen fuel cells. But do this after you have had a long hard look at energy efficiency and have at very least picked the low-hanging fruit.

The new StatoilHydro headquarters in Oslo will save energy by tapping geothermal heat in its heating and cooling system. Hot water will be pumped out of an old coal mine straight into office radiators; once the water cools it is pumped back into the mine to be reheated, naturally.

REDUCE YOUR CARBON FOOTPRINT

The refitting of Accenture's offices in Plantation Place was carbon neutral. By specifying carbon neutrality as part of the brief to designers, you can help promote sustainable design and fitting out of offices.

Encourage the use of public transport, bike, or car pooling for travel to and from the office, or investigate carbon offsets for your business activities. DEFRA's Nobel House office provides bicycle space for 10% of occupants. Alternatively, invest in equipment that reduces the need for air travel, such as video conferencing.

Fun with factoids

To stabilise carbon concentrations at around 550 parts per million by 2050 will mean using half the energy per dollar of output compared to 2002, an improvement in economic efficiency of 1.5% per year, 20% higher than has been achieved over the last 30 years. Pathways to 2050: Energy & Climate Change, WBCSD, 2005

AIR

BREATHE EASY

Fresh air, perfect temperature

Maintaining or improving air quality and thermal comfort can have a striking effect on staff health, alertness, well-being and productivity through:

- maximising individual control
- reducing heat gain, by using lighter coloured exterior surfaces to reflect sunlight from the building, shading devices, or increased daylight
- buildings that breathe – using natural ventilation as far as possible
- low-emission furniture, materials, paints and so on
- greenery, both indoors and outdoors for shading and air purification

In Morgan Lovell's London headquarters, heating and ventilation is zoned, giving more individual control, and thus ending the need to heat a whole floor based on one cooler spot. The office also uses a heat recovery system, using extra hot air from one part of the office to heat cooler parts.

Maximise individual control

West Bend Mutual Insurance Company in Wisconsin found that productivity rose by 16% due to a new sustainable building, of which 4-6% was attributed to allowing individual control of temperature, air flow, lighting and white noise. Energy costs dropped 40%. Complaints about temperature levels dropped from 40 per day (calculated to cost US\$25 per call) to two per week.

Energy use drops and productivity rises when people have more control over temperature and lighting levels. This can be as basic as allowing people to open and close windows, as well as more sophisticated sensors and controls.

The new DEFRA Alnwick headquarters is a “zebra” (Zero Emissions Building Renewing Alnwick), aiming for BREEAM’s new highest rating of Outstanding. DEFRA staff made clear they did not want an automatic system deciding when to open and close windows; rather they will have a system that guides them on when to open or close windows to create the best environment. Information combined with individual autonomy.

Reduce heat gain

Materials can reduce the need for air conditioning, whether due to their physical form, their chemical composition, or their colour, since lighter colours reflect the sun’s heat. Lawrence Berkeley National Laboratory has shown that roofs painted in pale pigments can strongly reduce heat gain and air conditioning needs of buildings.

You like your employees to multitask, so ask the same of materials used in office (re)design. Degussa’s Radiance is an interior paint that helps keep interior temperatures steady, reducing energy consumption for cooling and heating by up to 15%. Other wonder-paints include exterior paints that reduce heat gain from the sun, and Millennium Chemical’s Ecopaint which helps reduce outside pollution by working with sunlight to neutralise smog.

Buildings that breathe

Maximise natural ventilation and thermal regulation, such as through rooftop stack-assisted ventilation, or displacement ventilation, which allows air to pick up heat at floor level, taking it out the building via ducts or vents as it rises. Or look into wind towers mimicking ancient cooling systems in the Middle East, such as the Monodraught Windcatcher.

In the spirit of biomimicry, Loughborough, Cambridge and SUNY universities are studying termite mounds. Even in the desert, these mounds are models of self-regulating heat and ventilation. Tunnels and air conduits retain stable temperatures and moisture levels while wind energy drives air through the tunnels from the outside.

Go green, feel cool and be clean!

Greenery, inside and outside, can have a dramatic effect on air quality and the cooling.

- **Green roofs** - Chicago's City Hall has a 20,000 square foot green roof which has reduced air conditioning and heating costs by about US\$6,000 per year. It keeps the building cool in summer beneath a moist layer, and in winter provides additional insulation. Green roofs such as the Ford factory in Dearborn also have a role to play in storm water absorption, preventing drainage systems from being overwhelmed.
- **Hanging gardens** - the Aichi Expo 2005 planted a four-storey high vertical garden, called the Bio-lung, with roses, moss, vines and other plants to absorb CO₂, release oxygen and help cool the surroundings, reducing the so-called 'heat island' effect of built up areas.
- **Leafy shading** - planting deciduous trees near buildings can help with temperature regulation. Their summer leaves provide shade from the sun, while in winter the sun's heat can reach the building. Trees also lower the ambient outside temperature.

A tree planted near a city building saves ten times as much carbon dioxide as a tree planted in the forest because it reduces the energy used for air conditioning and helps to cool the city. Trees provide shade and soak up groundwater which then transpires through the leaves and further cool the air. A single properly watered tree can transpire 40 gallons of water a day through its leaves, off-setting the heat from eg 100 100-watt bulbs burning 8 hours a day.

Joseph Romm, Cool Companies

Tax incentives

The Enhanced Capital Allowance Scheme allows you to claim 100% capital allowance for the first year of an investment in energy (or water) efficient technologies or products, including:

- automatic monitoring and targeting
- boilers
- combined heat and power (CHP)
- compact heat exchangers
- heat pumps for space heating
- HVAC zone controls
- warm air and radiant heaters

LIGHT

LET THERE BE LIGHT

Lighting can have a massive impact on well-being, alertness and productivity. Artificial light is also a major source of energy consumption in itself and in the demand it can create for cooling. In the EU, indoor lighting uses some 14% of electricity in commercial buildings, and in the U.S. 37%, yet the IPCC (Intergovernmental Panel on Climate Change) reckons that lighting energy use can be reduced by 75-90%. To improve comfort and reduce energy use, you can:

- maximise the quantity and quality of daylight
- minimise glare from natural and artificial light sources
- install dimmable lighting with individual controls to allow for personal preference and different tasks
- use energy efficient lighting where possible
- use light colours for walls and other surfaces to reduce the need for artificial lighting

Natural, diffuse light

Designing the work environment to increase productivity requires first asking employees what they want. Compaq repeatedly surveyed and interviewed its workers to find out how they felt about their current workplaces and what they would like to see in a new facility. The single most common response concerned daylighting. People want as much natural light as possible in their office and would like to be able to see outside.

Joseph Romm, Cool Companies

Maximise daylighting through windows, clerestories and redirecting systems which can extend daylight deeper into the building than the usual 3-4 metre light perimeter provided by normal windows. This reduces energy use and heat generation, cutting down the need for cooling systems – creating a virtuous spiral of energy savings.

Examples include:

- light pipes which bring light from the roof to an interior room – they look like ceiling lights, only the light source is solar
- light shelves fitted in windows can reduce glare at the perimeter and increase lighting at the interior, reducing the need for artificial lighting and the contrast of glare and shade which is hard on the eyes. A school in Brazil found that learning improved by about 26% after light shelves were fitted in classrooms, creating evenly diffused natural light.
- shading devices to reduce direct sunlight, glare and heat.

Recreational Equipment Incorporated (REI) believes that the daylighting used in its flagship store results in customers lingering longer, for 1.5 to 2 hours per visit. They have consequently made daylighting a standard feature of all new stores. This applies to refits too: companies which have experimented by refitting one half of the premises to allow more daylight noticed that productivity – and sales – went up in the half with more natural lighting.

Dim the switch

Giving people control over lighting levels at their desks, in response to different tasks or personal preferences, leads to improvements in accuracy and alertness, and tends to lower overall lighting loads and costs. The tendency is to choose lower levels of light than designers would normally allow for. Consider, for example, automatically switching off main lights in an office after a certain time in the evening, so those working late use personal desk lights.

California Steel Industries refit workstations in its Drafting Engineering Department. After the upgrade they measured the light levels at every workstation over a 6-day period. Light levels varied with task, age, and personal preferences, but on average were much lower than standard design practice would suggest and much lower than the original levels of lighting. The personal lighting controls brought overall energy savings to more than 60%.

Joseph Romm, Cool Companies

Energy efficiency

Nobel House, a DEFRA office in London refurbished to BREEAM Excellent sustainability standard, uses a solar controlled smart system that dims electric lights automatically as natural light levels rise.

Choosing energy efficient lighting can have a significant impact on the overall energy use of an office. Sensors can monitor light and occupancy levels so that artificial lighting is never too bright or competing with sunlight, or wasted on empty rooms.

Fun with factoids

- lighting consumes about 40% of electricity in commercial buildings
- another 10% goes to cool the heat generated by lighting
- lighting energy use can be reduced by up to 90%

WATER

REDUCE THE USE & LOOP THE LOOP

The manufacturing processes used by DesignTex are so clean that the water effluent is safe to drink. The story goes that the water inspectors, finding the water cleaner coming out than going in, wondered if their instruments were faulty.

The basic principles of sustainable water use are conservation and recycling, which leads into grey-water (water than can be used for non-drinking purposes such as watering gardens or flushing toilets) and rainwater use.

Conservation

Pureprint is a waterless and alcohol-free process which produces 12.3% waste compared to 17.5% in conventional printing. In addition to being a much cleaner process, it offers sharper reproduction, increased ink densities, and brighter, clearer and more consistent colours.

Conservation can be direct and indirect. Indirectly, you could have your brochures printed using a waterless process such as Pureprint, or install Interface carpets that have changed their pattern printing processes to reduce water use in manufacture.

Or you could take the direct conservation approach and install low flush toilets and waterless urinals, such as in the [Genzyme offices](#) in Haverhill. Urine is 96% water, and yet we use great quantities of water to flush it away.

- waterless urinals using various sealants and water repellent coatings offer a waterless, odourless alternative, also saving costs in installation, piping and maintenance.
- dual flush and ultra low flush toilets – conventional toilets use about 23 litres of water per flush, whereas ultra low flush toilets use six.
- reduced flow taps and sensors that switch the tap on only in the presence of hands, so avoiding the huge wastage of taps left running or dripping

In refurbishing the Armstrong World Industries headquarters in Lancaster, Pennsylvania, water use was targeted as part of a (successful) bid to win LEED Platinum rating. Through the installation of water sensors, waterless urinals and dual-flush toilets, as well as uncovering waste and malfunctions in the humidification process, the building's annual use of potable water was halved from 800,000 to 420,000 gallons per year.

Recycling

The Ernst & Young headquarters in Amsterdam is big on rainwater harvesting. 65% of rain falling on the site is collected in a storage system, and much of it is used to fill a pond at the entrance to the office.

Water can be recycled, such as using the grey-water from hand-washing to flush toilets or water the garden. Rainwater can be harvested through porous paving or gently sloping surfaces that allow run-off to be collected - the refurbishment of the BP building in St James Square installed a rainwater harvesting system. It can then be used to water gardens or flush toilets, or for cooling systems.

Fun with factoids

- only 2.5% of water is fresh, of which 68% is trapped in glaciers and ice packs. 30% is in groundwater, and 0.3% is in freshwater lakes and rivers.
- the Environment Agency says rainwater harvesting could replace 55% of treated water in domestic use and 85% in commerce and industry.
- toilet flushing can use 30-40% of water in non-industrial buildings

MATERIALS

IT'S A MATERIAL WORLD

[TalkTalk](#) wanted to have their new head office for 830 people fitted out to BREEAM standards. They used more sustainable materials, such as FSC and PEFC certified wood products, and reduced waste to landfill by 92%, in addition to installing a sub-metering programme that monitored water, gas and electricity usage. The office won a BREEAM 'Excellent' rating.

DEFRA's approach to refurbishment covers some of the key elements of sourcing materials or products. Similarly, the refurbishment of BP's offices in St James Square managed to recycle 85% of its construction waste. Ask about:

- **Life cycle** – has it been designed to be robust, easily maintained or repaired, and do its components use renewable, recycled (or recyclable) materials?
- **Energy** – what is its energy consumption in manufacturing, transport and use?
- **Emissions** – what is its greenhouse gas (GHG) footprint? Does the supplier mitigate their GHG emissions? Does it give off other harmful emissions?
- **Water** – how much water was used in manufacturing?
- **Toxicity** – is it safe?
- **Weight** – could you use a lighter material or one with less volume, reducing transport impacts?

Ask suppliers some of these questions – even if they can't give perfect answers, just asking the questions will help create a demand and increase awareness of the issues.

When refitting the office of UK publishers [Egmont](#), Morgan Lovell used bookcases instead of walls and partitions, creating a flexible space, and reducing materials in the construction and in any future refits. They also installed carpets made of recycled materials with non-PVC backing so they can be recycled once they wear out. Paints were chosen with low VOCs (volatile organic compounds) and the kitchen flooring was made of Forbo, using more natural materials.

When [Talbot Underwriters](#) moved the business to one of London's landmark buildings, they went for a BREEAM "very good" rating. As the first tenant under a new landlord, they set a standard for others to follow. The 42,000 square foot refit included recycled glass worktops, Forest Stewardship Council (FSC) certified timber throughout, and A-rated finishes, even for the floors. It also included built in recycling stations to reduce waste, and to cut energy use (and bills), smart metering.

Interface aims to be one of the world's most sustainable companies, e.g.:

- Reclamation – the ReEntry™ programme reclaims old carpets, diverting 85 million pounds of materials from landfill in 10 years. The company mines these discards for their raw materials, such as their GlasBac®RE, a backing made from reclaimed and recycled carpet backing.
- Air quality – water based adhesives with very low volatile organic compounds (VOC) emissions
- Renewables – increasing use of renewable energy for manufacturing, and the use of corn or starch based polymers, so called biopolymers or bioplastics
- Waste – a goal of zero waste

Fun with factoids

- Bamboo grows in 4-5 years – it is stronger than steel, can have 8m overhangs in buildings, and stores 40 times more carbon than pine.
- Schmidt-Bleek estimates that on average, industrial products carry an ecological rucksack (the invisible impacts of their production) of about 30 times their own weight.
- Construction produces 19% of the UK's total annual waste – about 90 million tonnes, and 21% of hazardous waste.
- 30 million tonnes of that waste is off-cuts; 9.4 million is temporary works such as site hoardings and formwork; 2.9 million tonnes is simply due to damage
- Manufacture and distribution of construction materials accounts for about 10% of the UK's CO2 emissions.

FURNITURE

DURABLE & DATELESS

Herman Miller's Aeron chair has a breathable membrane which helps keep the body at ambient temperature. Normal foam and fabric backing increase body temperature and so the need for cooling. It's also 94% recyclable and comprises 64% recycled materials, and can contribute to LEED credits.

Many of the things to look out for in materials apply to furniture. In addition, consider:

- **Life cycle** – has it been designed to be robust, easily maintained or repaired, using renewable, recycled (or recyclable) materials; can it be refurbished to extend its useful life?
- **Desirability** – will its design endure in both aesthetics and functionality?
- **Modularity** – can it be reconfigured if you reorganise the office? Flexibility in office configuration can avoid regular refits.
- **Energy** – what is its energy consumption in manufacturing and transport?
- **Emissions** – what is its greenhouse gas (GHG) footprint? Does the manufacturer mitigate GHG emissions?
- **Water** – how much water was used in manufacturing?

There are several well known office furniture designers and manufacturers with impressive sustainability track records on design, process, maintenance and service, and recycling or refurbishment.

Deutsche Bank's refitted offices in Appold Street, London, used furniture from elsewhere in their estate. DEFRA's Nobel House refurbishment donated any redundant furniture to a charity for redistribution.

Herman Miller's mission is to 'contribute to a better world by pursuing sustainability and environmental wisdom'. They do this AND win awards for the beauty and ergonomics of their designs. Their Perfect Vision targets the year 2020 for zero landfill and hazardous waste. They provide detailed life cycle descriptions of their products, covering issues such as:

- durability and ease of maintenance, repair or disassembly
- recycled or recyclable materials
- low volatile organic compound (VOC) emitting paints and finishes
- returnable or recyclable packaging
- manufacturing processes, including air, water, energy use and emissions, waste, health and safety
- contribution to LEED accreditation

Steelcase uses recycled materials where possible, and avoids hazardous materials such as PVC, chrome, mercury, lead, or flame-retardants. They also simplify designs to reduce the number and weight of components. Their plastics are marked for recycling, and they provide environmental performance statements for products.

Steelcase's Please chair has 30% fewer components than its pre-2004 model. It has also been improved by 16% due to reduced weight and packaging. It can be upgraded and adapted since the fabrics, headrests and armrests can be added or removed. And it's easy to maintain.

Wilkhahn is also committed to making its products and processes sustainable. Water based systems for lacquering wooden surfaces has led to a 90% reduction in solvent use and emissions have been reduced by 21% through 'spot gluing' upholstery. Materials include biopolymers and lightweight sandwich boards, such as paper honeycomb from recycled paper. And like Herman Miller, they design for durability in aesthetics as much as in functionality – their furniture will look good, and not 'dated', even after 10 years or more.

Wilkhahn's ON chair used 55% recycled materials and is itself 96% recyclable. Due to its ease of assembly, the transportation volume is reduced by about 45% over conventional packaging. Again, it can earn LEED credits.

Fun with factoids

- Zody (Haworth) has won the Cradle to Cradle Gold award for its use of recyclable or mulchable fabrics and components, being 98% recyclable.
- Caper (Herman Miller) is 100% recyclable and has 21% recycled materials. It's easy to assemble and to take apart for recycling.
- Think (Steelcase) has 44% recycled materials and is 99% recyclable, taking about 5 minutes to disassemble with a screwdriver.

GOVERNMENT RESPONSES

WHAT WILL THEY HIT ME WITH (NEXT)?

In the last 10-15 years there has been a proliferation of policies, conventions, frameworks, directives and regulations governing sustainable development, with an emphasis on the environment, energy, carbon and climate change issues.

The latest development is the [CRC Energy Efficiency Scheme](#) (previously known as the Carbon Reduction Commitment), a cap and trade mechanism that kicked into operation in April 2010. It aims to deal with CO2 emissions not already covered by Climate Change Agreements and the EU Emissions Trading Scheme, and it is estimated that it will affect around 20,000 organisations, both public and private sector.

The [Climate Change Act 2008](#) introduced the world's first long-term legally binding framework to tackle climate change, with a view to helping the UK transition to a low carbon economy. It provides a legally binding target of an 80% cut in greenhouse gas emissions by 2050 with a reduction of at least 34% by 2020 from a 1990 baseline.

Since buildings are responsible for about 40% of EU final energy consumption, improving their energy efficiency could reduce their carbon emissions by 22%. This

led to the [EU Directive on Energy Performance of Buildings](#) which became national law in 2006. The Directive creates a common methodology for calculating the integrated energy performance of buildings and requires minimum standards for energy performance in new (and some existing) buildings, as well as energy certification for all buildings and inspections of boilers and heating and cooling systems.

Part L (Conservation of Fuel and Power) of the UK building regulations implements part of this Directive. It includes a requirement that if a building with a floor area of more than 1000 square metres has a major renovation, its energy efficiency should be upgraded as far as possible.

Another EU Directive, on end use energy efficiency and energy services, sets a target for a 9% cut in energy use from 2008 to 2017.

The UK government has also mandated that all new government buildings must achieve high ratings on the Building Research Establishment's Environmental Assessment Method (BREEAM): Excellent for new buildings and Very Good for existing buildings. Since public buildings comprise about 40% of the construction industry's work, the impact could be significant.

OVERVIEW OF SUSTAINABILITY

WHAT'S IN A WORD?

People & planet

An official, text-book definition of sustainable development (or 'sustainability') suggests holding up the edifice with the three 'pillars' of the environment, the economy and society.

This works in principle and even practice, but isn't an easy trio to digest conceptually, and nor does it readily engage the imagination. Yet sustainability can appeal to our instinctive admiration for systems or solutions that dazzle with their elegant response to complexity. The UK government, recognising that the standard language didn't have people begging for more, came up with a warmer definition most people can relate to.

The essence, then, is to bring about a mode of living and working that allows humanity to flourish in a flourishing natural environment, that irons out inequities between countries and regions, without compromising future flourishing. It 'converges human and natural flourishing so they work for rather than against one other over the long term'.

"At the heart of sustainable development is the simple idea of ensuring a better quality of life for everyone, now and for generations to come."

UK Government, Strategy for Sustainable Development, 1999

Planet & poverty

The midwife of 'sustainable development' was a collective realisation that we couldn't keep living as we were, 'borrowing' resources from poorer regions and future generations. The tipping point in terms of sustainability came recently, when we crossed a line from living within our ecological means to overspending accumulated natural capital and even selling off the family silver. In the 1960s we were at about 70% of carrying capacity (the human footprint the earth can bear without potentially triggering irreversible consequences). The US National Academy of Sciences has confirmed that we are now at about 120%. Do the maths.

The Millennium Ecosystem Assessment, drawing on about 1,400 experts in 95 countries, has found that ecosystems have been changed more in the last 50 years by human activity than at any comparable time in history. About two thirds of the ecosystems they looked at were degraded or being used unsustainably, and 0.5% of natural habitats are being lost each year, mostly to farmland.

www.millenniumassessment.org/en/index.aspx

The warp and woof of weaving towards sustainability (it isn't a straight path) is to simultaneously bring our collective overspend back within ecological, biodiversified budget, adapting to or repairing damage already done, while addressing inequities which mean that roughly 20% of the world's population consumes 80% of resources.

Balancing the budget

Tipping the budget into credit, buildings can already be designed that are not merely 90% less resource consuming, but which can be net producers of energy and clean air, feeding their surplus energy into the communal grid.

Government responses

The UN Framework Convention on Climate Change (the clunkily acronymed UNFCCC) was signed in 1992 and provides a non-binding target to stabilise global greenhouse gas emissions (GHG). The Convention established a yearly Conference of Parties, the so-called COP.

The Kyoto Protocol adopted in 1997 provides targets for developed countries to reduce their greenhouse gas emissions by 2008-2012 against a 1990 baseline year. International negotiations are now underway to come up with a new framework to succeed Kyoto when the Protocol expires in 2012.

Kyoto also allows for 'flexible mechanisms' such as the Clean Development Mechanism whereby developed countries gain 'credits' for investing in carbon-

reducing projects in developing countries. Such market mechanisms have been adopted by the EU through its Emissions Trading Scheme, launched in 2005.

The UNFCCC has a sister convention, the UN Convention on Biodiversity (UN CBD), which also has Conference of Parties (COP) meetings. The CBD COP 10, in Nagoya in October 2010, will see the results of the G8 sponsored initiative, The Economics of Ecosystems and Biodiversity (TEEB), putting some big (scary) numbers on the economic costs of biodiversity loss. Watch this space, ecosystems and biodiversity issues are likely to head into the same common parlance space that climate change now occupies.

Fun with factoids

- The UN Development Programme estimates that if the whole world were to have a similar lifestyle to that of developed countries today, it would need the resources of 5.5 earth planets.
- The Intergovernmental Panel on Climate Change estimates an increase in average temperatures of 2-4 degrees will bring more extreme weather events, leading to sea level rises and threatening sensitive ecosystems such as coral reefs.
- There is 10,000,000 km³ of water stored in underground aquifers. Since 1950 there has been a rapid expansion of groundwater exploitation providing 50% of all drinking water, 40% of industrial water and 20% of irrigation water.

WHERE CAN I SURF MORE?

SUSTAINABLE DESIGN & BUILDINGS

General

[Advanced Buildings](#) is a superb source of briefings on a range of sustainable building topics such as lighting and daylighting, finishes and furnishings, heating and cooling, water use and heating, building automation systems, energy efficiency, stormwater management, and air quality. A great place to start learning.

The [UK Green Building Council](#) was launched in 2007, bringing together companies from across the building industry spectrum.

The [US Green Building Council](#) is a fount of fine information, including the LEED rating system.

The [Rocky Mountain Institute](#) has a website full of delights on the topics of energy efficiency, retrofits and sustainable architecture in general.

[GreenSource](#) provides a range of excellent articles on sustainable design in buildings. Worth visiting from time to time to see what's new.

'[Buildings that breathe](#)', by Richard Lacayo, is an inspiring article on how the 'best of the new architecture uses nature rather than fighting it'.

[Metropolis Magazine](#) has a section devoted to sustainable design, with often excellent articles.

'[Before the First Pour: Design Guide for Energy Efficient Commercial Fit-Outs](#)' is a superb, short introduction to the subject by the New Zealand Energy Efficiency and Conservation Authority.

The down-to-earth [Whole Buildings Design Guide](#) provides an outline of sustainable building concepts and products, including a specific focus on [office buildings](#).

The authoritative [Building Research Establishment](#) is a key player in making the UK building sector more sustainable. It does research, dispenses advice, disseminates information and develops tools. It is the brain behind the BREEAM sustainable building ratings.

[Building Green](#) is a subscription based on-line resource that provides practical information. It includes [case studies](#), freely accessible, of high performance office buildings.

The [Sustainable Building Information System](#) has a great deal of freely available information. You can search websites for technologies, buildings, documents, methods and tools, people and organisations, projects, policies and programmes.

The [Association for Environment Conscious Building](#) is a member-based organisation, providing training, articles and conferences. It has straightforward Eco Fact Sheets, covering energy, pollution, water and biodiversity.

The Commission for Architecture and the Built Environment (CABE) website has a section on [sustainability](#).

Tools

These [Sustainable Buildings Guidelines](#) by the University of Minnesota take you through a process of selecting sustainable design strategies and documenting your actions.

The [pool of tools](#), a directory of hundreds of tools on building performance, materials, components, equipment, HVAC and lighting systems, air quality, you name it. You can search by subject or country. All you ever wanted to know about tools, but were afraid to ask.

Sust is a Scottish initiative for sustainable building design, including a [Green Directory](#) of suppliers.

The [Building Research Establishment Environmental Assessment Method](#) (BREEAM) can be used to assess both new and existing buildings. It includes the widely used [BREEAM for Offices](#).

[Leadership in Energy & Environmental Design](#) (LEED™) Green Building Rating System. LEED is one of the leading systems for rating sustainable buildings, devised by the US Green Building Council. This is a clear overview.

[Practical Strategies in Green Building: Existing Offices](#) is a short guide for office owners and managers for strategies to obtain LEED certification, but is relevant to anyone needing a neat checklist of things to consider.

[Building for Environmental and Economic Sustainability](#) (BEES) is a tool to help assess about 200 building products, both generic and branded.

Building magazine has a section on [sustainability](#), including guidance and reports on legislation and other issues.

Conferences

The [International Conference on Improving Energy Efficiency in Commercial Buildings](#)

The [Building Performance Congress](#)

The [Global Conference on Sustainable Building and Construction](#) will be held in London in 2011.

Awards

[The BREEAM Awards](#) recognise the best of sustainable building design in the UK.

Building magazine has an annual [award for sustainable building design](#), including Sustainable Designer of the Year, Sustainable Client of the Year, Sustainability Innovation Award, Sustainable Building of the Year and others. The 2009 conference and award were organised with the UK Green Building Council.

An initiative meant to encourage better and more sustainable public buildings, with success recognised through the Prime Minister's [Better Public Building Award](#).

There is an annual award from the [EU's GreenLight](#) programme.

WHAT ARE THE BENEFITS?

The UK Green Buildings Council has done a superb, concise review of the literature on the business case for green buildings. Completed in March 2009, this can be [downloaded](#).

'[Doing Well by Doing Good? Green Office Buildings](#)', by Piet Eichholtz, Nils Kok, John M. Quigley (January 2009), looked at 10,000 buildings to determine whether those with "green" ratings commanded higher rent (yes, they do).

Cost savings

[Ten Business Reasons to Green Your Office](#) lays out some simple arguments.

'[Green construction cost effective](#)', a feature in McGraw-Hill Construction, argues just that.

[Envirowise](#) provides a plethora of guides, case studies, checklists, workshops and other services to help companies cut costs by reducing their environmental impacts and energy use. Many of the materials are relevant to office design and management, and there is a section dedicated to [construction](#).

Productivity

[Cool Companies](#) give a number of short case studies of improved productivity brought about by energy saving measures.

'[Why office design matters](#)' by Thomas Davenport for Harvard Business School, looks at the link between office design and human productivity.

[The Office Productivity Network](#) aims to help managers understand how the design of their office environments can affect productivity.

Incentives

[The Enhanced Capital Allowance Scheme](#) permits you to claim 100% first year capital allowances for investments in energy saving technologies and products which are on the Energy Technology List. This website gives the list, together with tools and criteria to help with applications.

[The Landfill Tax](#) is a fiscal incentive to minimise waste, which will increase until it reaches £35 per tonne. For further guidance on waste reduction incentives, see the DEFRA page on waste.

[The Aggregates Levy](#) aims to encourage the use of recycled aggregates by taxing virgin aggregates.

WHAT SHOULD I LOOK FOR?

General

This [Sustainability Checklist](#) by Morgan Lovell is a quick, clear starting point. It is complemented by an Environmental Fact Sheet that helps you find your way around various key environmental performance certification schemes.

'[Greening your office building](#)' is a brief introduction, in McGraw-Hill Construction, to the competitive advantage that sustainable office design can yield.

[Advanced Buildings](#) is a superb source of briefings on a range of sustainable building topics such as lighting and daylighting, finishes and furnishings, heating and cooling, water use and heating, building automation systems, energy efficiency, stormwater management, and air quality. A great place to start learning.

One of the most concise yet comprehensive guides to sustainable office design, [A Guide to Sustainable Office Fit-Outs](#), can be downloaded free. A real step-by-step How To guide, covering paint, cabling and wiring, Heating, Ventilation & Cooling (HVAC) systems, lighting, glazing, materials, water, energy, furniture, noise and safety. It provides excellent technical checklists and things to ask for and to avoid. Jargon-free language!

[Working 9 to 5 on Climate Change: An Office Guide](#) is a step-by-step guide in the plainest language, with checklists and examples to help office managers reduce the environmental impact of the workplace. It can be downloaded, and is worth distributing around the office.

'[The art and science of peace and quiet](#)' by Sara Hart is a well-written, concise yet comprehensive introduction to dampening noise in buildings.

ENERGY

General

[Transforming the Market](#) is a short report produced by the Energy Efficiency in Buildings project of the World Business Council for Sustainable Development. The report summarises the findings of a model developed to assess the impact of different policies, measures and technologies in shifting towards zero net energy buildings. The report is supplemented by a [roadmap](#).

[Cool Companies](#) is the website that goes with the book of the same title. Clear guidance on a range of issues affecting energy use.

[High Performing Buildings](#) is a magazine of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) which includes an energy focus.

The US Department of Energy has a [Building Technologies Program](#) with excellent information on energy efficiency and renewable energy.

Tools

[RIBA's Climate Change Toolkit](#) is a clear simple starting block.

[Envirowise](#) has a plethora of materials: guides, case studies, checklists and reports that can help companies reduce their energy use.

[The pool of tools](#), a directory of hundreds of tools on building performance, materials, components, equipment, HVAC and lighting systems, air quality, you name it. You can search by subject or country. All you ever wanted to know about tools, but were afraid to ask.

The [Climate Change Projects Office](#) advises business on how to adapt to climate change, and even how to take advantage of it.

Renewables

[‘Switching to Green: A renewable energy guide for office and retail companies’](#) is a short, clear guide for companies that would like to shift to renewable energy supplies but aren't sure how

The US Department of Energy has a page dedicated to [on-site renewables](#).

AIR

General

[‘Here's the dirt on green housekeeping’](#) is a short, clear piece by Nancy Solomon (Architectural Record) which considers the maintenance and monitoring procedures and systems needed to keep the indoor environment healthy.

[‘Robo buildings: Pursuing the interactive envelope’](#) by C.C. Sullivan in Architectural Record is an entry to the world of smart building envelopes that incorporate ventilation and daylighting to the benefit of occupants and the environment.

[The American Society of Heating, Refrigerating and Air-Conditioning Engineers](#) (ASHRAE) is known for setting standards in HVAC energy use.

[Energy Master Planning for HVAC Systems in Existing Buildings](#) is a good starting point, which puts sustainable heating, cooling and ventilation in the framework of The Natural Step.

Ventilation

[Natural Ventilation](#) is a jargon-free overview of natural ventilation, although the codes and standards part relates to the US only. By Andy Walker, National Renewable Energy Laboratory.

[‘Commercial buildings open their windows’](#) by Barbara Knecht and Sara Hart is a crystal clear introduction to natural ventilation via windows; another engaging feature in Architectural Record.

The Energy Conservation in Buildings and Community Systems Programme is an International Energy Agency initiative to improve the energy efficiency of buildings, with various research projects including [Control Strategies for Hybrid Ventilation in New and Retrofitted Office Buildings](#).

[The Sunpipe](#) is produced by the company that produces the Monodraught Windcatcher, a rooftop ventilation system that eliminates air conditioning, and the Sola-Vent which combines light piping and solar powered ventilation.

[Silenceair](#) allows natural ventilation while blocking outside noise by up to 85%.

Heating & cooling

[Passive Solar Heating & Cooling Manual](#) is a simple introduction to the subject with clear diagrams and language; passive solar heating and cooling 101.

Indoor air quality

'[Enhance Indoor Environmental Quality](#)' is a short on-line guide to what you need to bear in mind, with useful links to additional resources.

To tap research on ventilation rates and technologies, indoor volatile organic compounds (VOCs), sick building syndrome and air pollution, see this [Lawrence Berkeley Laboratory page](#).

Access to a bibliography of 900 papers (many with abstracts) for the [Indoor Health and Productivity Project](#).

The subscription-based Building Green has a section on [Indoor Environmental Quality](#). [Greenguard](#) certifies low emission products for the indoor environment, including adhesives, appliances, ceiling, cleaning systems, flooring, construction, insulation, office equipment, office furniture, panels and moveable walls, paint, textiles and wall coverings. Although a US standard, their Allowable Emission Levels provide a great benchmark for suppliers.

LIGHT

Daylighting

See this [short introduction](#) to the benefits and concepts of designing for maximum daylight.

Another [short sweet introduction](#), covering pros, cons, devices, controls and costs, all in five pages, with a few more on resources if you wish to dig deeper.

This [Lawrence Berkeley Laboratory](#) site has sections on Glazing Materials, Window Properties, and Commercial Performance.

[‘Daylighting Guide for Canadian Commercial Buildings’](#) can be freely downloaded from the website of the Public Works and Government Services of Canada. Fairly concise and readable, it also provides some brief case studies.

Links to the [‘Daylighting in Commercial Buildings Sourcebook’](#) and ‘Daylighting The New York Times Headquarters Building’.

A straightforward [tour of daylighting](#), under this section on energy efficient lighting.

[The company](#) that produces the Sunpipe, an aluminium light pipe for bringing daylight into a building interior, and the Sola-Vent which combines light piping and solar powered ventilation.

Another maker of [light pipes](#), or ‘miracle skylights’.

Lighting

[Guide to Sustainable Office Lighting](#) – very short and simple overview.

A short guide to [energy efficient lighting](#), well illustrated and clearly written. A good starting point.

A brief guide to [electric lighting controls](#), such as photosensors and occupancy sensors, which can make a big difference to productivity levels (up) and energy bills (down).

The [Lawrence Berkeley National Laboratory](#) does wide ranging research on windows, daylighting, lighting systems, and commercial buildings systems.

They also have a [Lighting Research Group](#) addressing these issues.

The [Human Factors](#) research team considers how lighting affects productivity.

Linked to productivity is the capacity to improve control of lighting. The [Control and Communications](#) research group is considering how digital technologies can be applied to building lighting controls.

[Lightsearch](#) is a source for lighting products and manufacturers.

[The Intelligent Workplace](#) has suggestions for lighting and lighting controls.

A straightforward tour of various forms of [energy efficient lighting](#). A good place to start.

The EU’s [Greenlight Programme](#) aims to encourage more energy efficient lighting. It has an annual award, and an e-newsletter. It also has an [excellent overview](#) of energy efficient lights and a guide to action.

The Energy Conservation in Buildings and Community Systems Programme is an International Energy Agency initiative to improve the energy efficiency of buildings, with various research projects including [Annex 45 Energy-Efficient Future Electric Lighting for Buildings](#).

Superwindows

The Lawrence Berkeley Laboratory site has sections on [Glazing Materials, Window Properties, and Commercial Performance](#).

[Efficient Windows](#) provides a wide-ranging introduction to technologies around energy efficient windows and tools for selecting them, including a detailed glossary and access to superwindow information. Although quite US-oriented, it's still valuable to a European.

The Center for Sustainable Building Research at the University of Minnesota has a site dedicated to [energy efficient windows for commercial buildings](#).

WATER

General

'[Greening your site](#)', by Heather Kinkade-Levario is a short article looking at how low impact techniques can maximise water conservation.

[Sustainable Sources](#) has a clear guide to several key aspects of sustainable buildings, including a section on water.

The [Interflush](#) is a device for reducing water use in flushing.

The [UK Rainwater Harvesting Association](#) is a good place to start.

[The Global Water Tool](#) is a free, easy-to-use, Excel based tool that allows companies to punch in water-use data from their operations and have these compared to external water availability data. Gives a quick assessment of where you need to focus your water management action. Developed by the World Business Council for Sustainable Development.

MATERIALS

General

Sustainable Sources is clear guide to several key aspects of sustainable buildings, including a section on [building materials](#).

[The BRE Centre in Innovative Construction Materials](#) is a research and development partnership between the Buildings Research Establishment and Bath University.

Tools

[Greenseal](#) provides some very clear and concise guides to specifying a range of materials and products, including particleboard and medium density fibreboard, carpet, lighting, occupancy sensors, office supplies and other office relevant products.

[Transmaterial](#) is a joy to behold, taking you through a range of new materials. Although not specifically 'sustainable' materials, many of them come with environmental features which are briefly outlined. There is also a richly illustrated book of the same name.

BRE has a [Green Guide to Specification](#) which is easy to use and full of guidance.

This is the [Environmentally Preferable Purchasing](#) page of the US EPA providing guidance on a range of building related products; very clear information.

This is the [pool of tools](#), providing a directory to hundreds of different tools concerning analysis of building performance, with a section dedicated to materials and components.

[Building for Environmental and Economic Sustainability \(BEES\)](#) is a tool that helps assess about 200 building products, both generic and branded.

The [EcoLogo](#) of the Canadian government allows you to assess a wide range of building materials and products, including flooring, heating and cooling, paints and finishes and raw materials.

[Greenspec](#) is an excellent, enjoyable on-line resource for specifying more sustainable materials and products.

The Waste & Resources Action Programme, funded by government, aims to create markets for recycled materials. It has a section specifically dedicated to [reducing waste in construction](#) – excellent and clear.

[Sust.](#) provides a directory of sustainable building materials in Scotland.

[Website of the BC](#) (formerly known as the BioComposites Centre) which develops plant-based composite materials for industrial use, including a project looking at plant-based MDF. They have a newsletter to which you can sign up.

[Greenguard](#) certifies low emission products for the indoor environment, including adhesives, appliances, ceiling, cleaning systems, flooring, construction, insulation, office equipment, office furniture, panels and moveable walls, paint, textiles and wall coverings. Although a US standard, their Allowable Emission Levels provide a great benchmark for suppliers.

Boards

[The Natural Building Technologies](#) website has a section on boards, plaster and render, including avoidance of the 'sick building syndrome' through breathable renders. It includes a [checklist](#) of natural insulators, including some wood fibre boards which can be used for walls, floors, ceilings as well as roof insulation.

[PrimeBoard Inc](#) manufactures wheat board, a fibre board using wheat stalks which would otherwise go to waste. They also make DorCor, low density panels from renewable resources such as wheat straw and sunflower hulls, and formaldehyde-free, emission-free synthetic resins.

Carpets

[Interface](#) is the global leader in developing sustainable carpets.

Ceilings & flooring

[Armstrong World Industries](#) is known for a commitment to sustainability in its ceiling and flooring products. It also offers cabinets.

[Plyboo](#) is a product made from a strong, light, fast-growing renewable resource: bamboo. It can be used for flooring (harder than many woods), panels or doors.

'[Bamboo in construction: is the grass always greener?](#)' is an excellent overview of bamboo as a building material, looking at all aspects of its sustainability performance, from Environmental Building News, 2006.

Paints & finishes

'[Eco and Natural Paints](#)', by Neil May, is a readable, concise article on the ecological effects of paint, from the Natural Building Technologies website.

Textiles

[Designtex](#) is one of the main suppliers of fabrics designed for minimal environmental impact. Their Climatex Lifecycle started by designing 'out' as many chemicals as possible to create a fabric that can be composted. Climatex Lifeguard FR has the same mulchable qualities while meeting worldwide fire retardant safety codes. Eco Intelligent Polyester uses environmentally benign materials while Terratex is 100% recycled polyester. Designtex has produced guidance on how their products can contribute to LEED credits.

Wood

[The Forest Stewardship Council](#) is the certifier par excellence of sustainable timber.

[The Sustainable Procurement of Wood and Paper-based Products Guide and Resource Kit](#) helps navigate a plethora of standards and certification schemes. Developed by the Sustainable Forest Products Industry group at the World Business Council for Sustainable Development.

GOVERNMENT RESPONSES

Directives & legislation

This [site](#) can help you keep up with current and emerging environmental legislation. Similarly the [Department of Energy and Climate Change](#) has a useful page on legislation.

[The CRC Energy Efficiency Scheme](#) kicked off in April 2010. There are some excellent materials to help you ascertain if you are eligible (liable) and if so, to navigate the scheme.

'[The CRC Energy Efficiency Scheme: User Guide](#)' by the Department of Energy and Climate Change is crystal clear (and even colourful).

The [Carbon Trust](#) has also produced a helpful guide to Managing CRC as Business Opportunity.

'[Managing the CRC as a business opportunity](#)' is a short, straightforward overview by Paul Kelly at Morgan Lovell.

The Environment Agency also has a [CRC website](#).

The [Enhanced Capital Allowance Scheme](#) allows you to claim against tax for capital investments in energy efficient or water saving plant and machinery, and low emission cars.

[EU Directive on Energy Performance in Buildings](#) was implemented at national level in January 2006. The [Directive Implementation Advisory Group](#) can help you figure out what it all means.

[The Sustainable and Secure Buildings Act](#) 2004 allows building regulations to consider sustainability more broadly to include not only environmental improvements, but also furthering sustainable development, and the reduction of crime.

The Update to Part L of building regulations sets standards to reduce CO2 emissions. It looks at overall CO2 emissions against a target value and will take into account any renewables used. See these [Frequently Asked Questions](#) on Part L and proposed changes.

[The Climate Change Levy \(CCL\)](#) effective since 2001, as tax on energy use in industry, commerce and the public sector. See this [Carbon Trust Factsheet](#).

Codes & standards

There is also discussion about whether to develop a Code for Sustainable Buildings (CSB). See this UK Green Buildings Council paper on the [case for such a code](#).

The [Building Research Establishment Environmental Assessment Method \(BREEAM\)](#) can assess new and existing buildings. Its widely used BREEAM for Offices assesses office buildings. It has five levels: Pass, Good, Very Good or Excellent and, added recently, Outstanding.

OVERVIEW OF SUSTAINABILITY

The government's mouthpiece on its [sustainable development strategy](#).

'[Sustainable Development Indicators in your Pocket 2009](#)' is an excellent annual overview of sustainable development indicators and facts in the UK, compiled by the government and presented in a graphic-rich design, even though it isn't quite pocket-sized. There is also a [Powerpoint version](#).

The [World Business Council for Sustainable Development](#) is a coalition of 200 multinational companies looking for ways to make business and sustainability work for each other. The website has been voted the best on-line resource on sustainable development and the organisation produces a wide range of tools, research, newsletters and policy guidance. It has an [Energy Efficiency in Buildings](#) project.

The [Millennium Ecosystem Assessment](#) brought together about 1,400 scientists from 95 countries and examined the state of the planet, looking at ecosystems, biodiversity, degradation and other issues including human impacts. It offers some manageable synthesis reports.

The [Design Council's](#) website has a section on sustainability, with an emphasis on design and a range of resources, short case studies, and content on trends and other emerging issues.

The [Intergovernmental Panel on Climate Change \(IPCC\)](#) – global authority on climate change.

[The Sustainable Development Commission](#) was set up by the government as an independent advisory body.

WHERE CAN I DIG DEEPER?

There are hundreds of books on every one of the topics covered here. Below is a small sampling, to give you a taster of what's out there, listed alphabetically by author under a few key headings: Buildings, Materials and General. Some are for inspiration and others more for implementation.

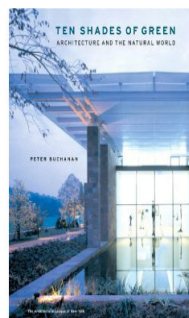
BUILDINGS



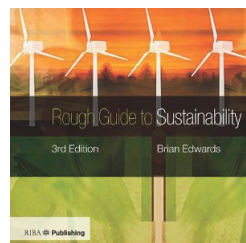
[Daylighting Performance and Design](#), Gregg Ander (Wiley, 2003), provides uncluttered language and clarity. ISBN 04712 62994.



[Sun, Wind & Light: Architectural Design Strategies](#), GZ Brown and Mark DeKay (John Wiley, 2001). A real inventory of approaches to heat, light, ventilation, energy and other elements of sustainable building. This is in the How To department and includes analysis techniques. Really for practitioners. ISBN 04713 48775.



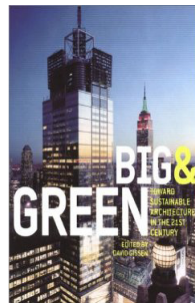
[Ten Shades of Green: Architecture and the Natural World](#), Peter Buchanan (The Architectural League of New York, 2005). Along with Big & Green, this is a great inspirer, bringing sustainable architecture to life through some excellent examples, opulently photographed and illustrated. A joyous way to impart the basic principles of sustainable building design. ISBN 03937 31898.



[Rough Guide to Sustainability](#), Brian Edwards (RIBA Enterprises, 2005). An excellent, short, readable introduction to sustainable architecture, including drivers, policies and regulations, as well as techniques. Full of crisp illustrations and diagrams. A good starting point. ISBN 18594 61743.

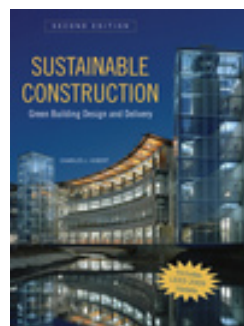


[Green Buildings Pay](#). Brian Edwards, 2nd edn (Taylor & Francis, 2003) gives an overview of office and school design with case studies (including the views of the designers and the client) to demonstrate that more sustainable buildings make sense financially and demonstrably raise productivity. Perhaps most pertinent is the chapter 'The Relevance of Green Buildings to the Procurement and Marketability of Offices'. ISBN 04152 62712.

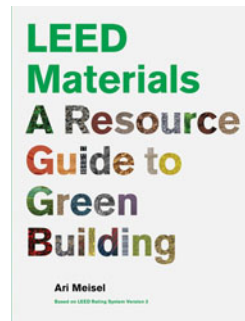


[Big & Green: Toward Sustainable Architecture in the 21st Century](#), edited by David Gissen (Princeton Architectural Press, 2002). A visual and conceptual feast, to read or give to people to trigger enthusiasm and inspiration. Suitable for all audiences, it covers Energy, Light & Air, Greenery, Water & Waste, Construction and Urbanism and includes interviews with some of the key movers and shakers in this field, such as Robert Fox or William McDonough. A coffee table book with guts and substance. ISBN 15689 83611.

[The Distributed Workplace](#), edited by Andrew Harrison, Paul Wheeler and Carolyn Whitehead (Spon Press, 2004). Coming at it from a different angle, this is how to enable people to work in decentralised environments in a collaborative, flexible way by making the most of communications technologies. It has implications for energy use, transport and employee well-being and productivity. ISBN 04153 18904.



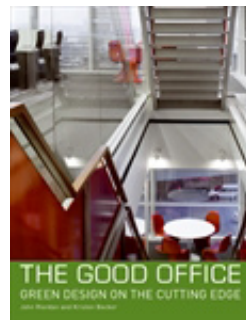
[Sustainable Construction: Green Building Design & Delivery](#), Charles J. Kibert, 2nd edn (John Wiley, 2007). Excellent, solid, readable book for when you're ready to dig in seriously. Covers a wide range of issues, from tools and standards, to the design and building process, landscaping, water, energy and atmosphere, indoor air quality, materials use, commissioning and economic analysis of sustainable buildings. Full of information and as relevant to the practitioner as to the generalist. Although it covers technical issues, it's accessible. ISBN 97804 70114 216.



[LEED Materials: A Resource Guide to Green Building](#), Ari Meisel (Princeton Architectural Press, 2010). Does what it says on the tin. ISBN 97815 68988 856.



[Guide to Green Building Rating Systems](#), Linda Reeder (John Wiley, 2010). Helps navigate through the burgeoning rating systems being applied to buildings. ISBN 97804 70401 941.



[The Good Office: Green Design on the Cutting Edge](#), John Riordan and Kristen Becker (Harper Collins, 2008). A sumptuously illustrated collection of case studies; not a technical how-to, but a good place to get some ideas and inspiration. ISBN 97800 61537 899.



[Introduction to Architectural Science: The Basis of Sustainable Design](#), Steven Szokolay, 2nd edn (Architectural Press, 2008). If you started with the Rough Guide to Sustainability, you might try this one when you're ready to dig in deeper. It's getting into the nitty-gritty how-to stuff, with a particular emphasis on Heat, Light and Sound. Only for practitioners, but well presented and illustrated, and avoids feeling like a textbook. ISBN 97807 50687 041.



[Retrofitting Office Buildings to be Green and Energy-Efficient](#), Urban Land Institute, 2010. A one-stop shop on retrofitting office buildings, from the inside out, this includes case studies, trends and certification, and a discussion of public policy. It is clear and well illustrated. ISBN 97808 74201 338.



[Biodiversity for Low and Zero Carbon Buildings: A Technical Guide for New Build](#), Dr Carol Williams (RIBA Publishing, 2010). Biodiversity is going up the agenda and is an issue with which companies will increasingly have to grapple. This provides practical guidance to taking biodiversity into accounting in designing new buildings, and also summarises current legislation governing biodiversity in the UK. ISBN 97818 59463 536



[Smart & Sustainable Built Environments](#), Jay Yang (ed) (Blackwell Publishing, 2005) covers a range of state of the art methods and technologies, including emerging tools and approaches. There are several chapters specifically relevant to sustainable office design: technical solutions, reducing energy related emissions, the increasing costs of commercial buildings once emissions trading is factored in, and raised floor systems for office fit-outs. Many other chapters are also relevant. ISBN 14051 24229.

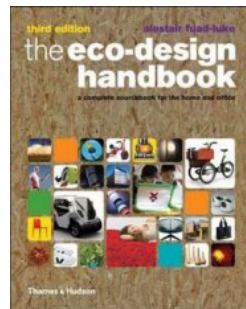
MATERIALS



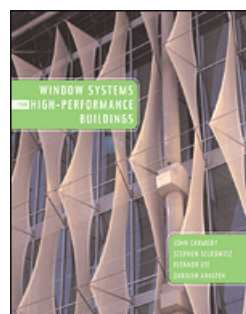
[The Green Guide to Specification](#), Jane Anderson, David Shiers and Kristian Steele (Wiley-Blackwell, 2009), this fourth edition provides an easy introduction to the environmental performance of both interior and exterior construction materials. ISBN 97814 05119 610.



[Transmaterial 3](#), Blake Brownell (ed) (Princeton Architectural Press, 2010), is the third volume in a joy of a series for designers interested in exciting new materials. Although not specifically aimed at sustainable design, it provides an environmental summary for a large proportion of entries, which should remove any notion that sustainable design is about using recycled egg cartons. Beautifully illustrated, with detailed information on properties and suppliers. You can also read about many of the entries on the website, but you won't have the tactile or visual pleasure of the book version. ISBN 97815 68988 931.

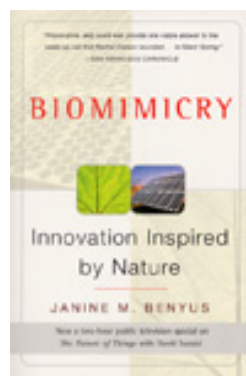


[The Eco-design Handbook: A Complete Sourcebook for the Home and Office](#), Alastair Fuad-Luke (Thames & Hudson, 2009). A new and improved edition of this book, great to dip into for ideas on materials and products of a sustainable bent. It also provides guidance and information on suppliers and other useful contacts. Although not aimed at buildings, some of the materials and furniture are relevant. ISBN 97805 00288 399.

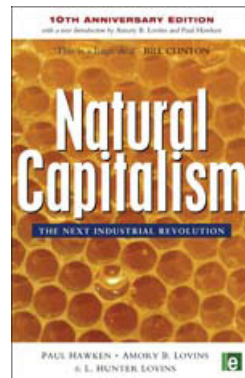


[Window Systems for High-Performance Buildings](#), John Carmody, Stephen Selkowitz, Eleanor S. Lee, Dariush Arasteh and Todd Willmert (US Department of Energy, 2004).

GENERAL



[Biomimicry: Innovation Inspired by Nature](#), Janine Benyus (William Morrow, 1998), is a delight for the mind for anyone interested in seeing the potential of sustainable design, even if they don't think of biomimicry as being their thing. It is beautifully written, a rarity in this field, and is full of inspiring ideas and stories. ISBN 06881 60999.



[Natural Capitalism: The Next Industrial Revolution](#), Hawken, Paul, Amory & Hunter Lovins (Earthscan, 2010) is the second edition of the read-this-if-nothing-else introduction to sustainable design in its broadest sense. The chapters on building design and tunnelling through the cost barrier are particularly pertinent, the latter demonstrating that optimising a whole system, rather than its parts, can yield compound simplicities and savings. Highly readable and inspiring. ISBN 97818 44071 708.



[Cradle to Cradle: Remaking the Way We Make Things](#), William McDonough and Michael Braungart (North Point Press, 2002). A slim introduction to the cradle to cradle philosophy of going beyond merely being efficient to creating virtuous closed loops in production. Highly readable and inspiring, and though not specifically building oriented, it has transferable principles. Cradle to Cradle now also includes a product certification scheme. ISBN 97800 99535 478.



[Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions](#), Joseph Romm (Island Press, 2006). Although over a decade since first published, Cool Companies is still one of the best introductions to using sustainable design to unleash the productivity giant. The chapters on lighting, heating and ventilation are the most pertinent. Gives scores of examples of refits to commercial buildings which had short payback times and productivity gains that exceeded all expectations; and things are better now than they were then in terms of materials and technologies. It also provides some straightforward How To advice. ISBN 97815 97261 166.



[Factor Five: Transforming the Global Economy through 80% Improvements in Resource Productivity](#), Ernst von Weizsäcker, Karlson 'Charlie' Hargroves, et al (Earthscan, 2009). This is a new and improved, updated, colour-illustrated version of the classic Factor Four, published in 1997. There is one rich, fat chapter dedicated to the Buildings Sector. ISBN: 97818 44075 911.

WHAT DOES IT ALL MEAN? GLOSSARY

Around the world in eighty words? A quick tour of the jargon:

Biomimicry – science studying nature as a sourcebook for designing new materials, structures, processes and systems. A cornucopia of ideas and well-tested techniques.

Carbon credits – buying the right to produce carbon emissions from those whose production is below an agreed threshold.

Carbon neutral – operating in a way that does not produce net carbon emissions. This can be through making your own emissions 'neutral', or through 'off-setting', buying carbon credits from others.

Carbon footprint – the CO₂ emissions you produce relative to any given activity or output.

Carbon off-sets – similar to credits, off-setting your carbon emissions could involve investing in a forest conservation project somewhere to mitigate the effect of your activities on climate change.

Climate change – the signals coming from the planet that human activity may have pushed things too far. Often referred to as 'global warming' although this suggests that things can only get warmer and doesn't allow for the rag-bag of climatic changes that could emerge from high concentrations of CO₂ and other greenhouse gases.

Climate neutral – having no negative effect on climate change.

Closed loop – the art of creating systems, from factory to global trading, that mimic ecosystems by moving from a linear to a circular flow of materials and energy. Think of a lake rather than a river.

Cradle to cradle – another term for closed loop, and a broader notion of life cycle thinking than the formerly used 'cradle to grave'.

Daylighting – maximising natural light through windows and other means such as light pipes (bringing natural light from the roof) and light shelves (bringing natural light from windows deeper into the building than the normal 3-4 metre perimeter). Daylighting reduces the need for artificial lighting and with it the demand for cooling. There's also growing evidence that humanoids like natural light and are more alert, content and productive than in artificial light.

Dematerialisation – reducing the ratio of materials to results, by using fewer or lighter materials, or finding new business models that put the emphasis on selling performance or benefits, rather than products.

Dimming controls – the ability to raise or lower lighting levels. Evidence suggests that people use lower levels of lighting than conventional wisdom has imposed on them, triggering considerable reductions in energy use.

Displacement ventilation – capitalising on the fact that heat rises to create ventilation systems that take excess heat up and out of vents or ducts in the roof.

Eco-efficiency – linking environmental and economic efficiency, this is a key strategy on the road to sustainability, but in itself will not lead there as it doesn't address some underlying systemic flaws in our production systems. Still worth pursuing alongside other strategies.

Ecological rucksack – the invisible (to the user) 'baggage' carried by most products in the form of the energy, materials and negative environmental effects that went into their manufacture and transport. This baggage can be hundreds or even thousands of times greater than the product itself.

Ecosystem services – the realisation that ecosystems provide many irreplaceable services to us free of charge, such as pollination by bees, flood prevention, air cooling and cleaning, soil conservation or water filtration. People are beginning to see the huge cost benefits of preserving these services. One example: New York State realised that fertiliser run-off was polluting its water supply and that it would cost billions less if they bought up rural land around the watershed and paid farmers an annual subsidy NOT to cultivate the land, than if they invested in conventional water treatment facilities. DuPont found that investing in wetland development acted as a water treatment buffer which not only encouraged biodiversity (and good brand reputation) but cost about 25% the conventional treatment route.

Emissions trading – using market mechanisms to reduce carbon or other undesirable emissions. The EU Emissions Trading Scheme is the standard on carbon trading. The US has been trading sulphur dioxide for years and US companies have voluntarily established the Chicago Climate Exchange for a range of greenhouse gases.

End of life – the idea that products have a linear life, and once it's over, they die. This is being challenged by the notion that products, or at least components, can be reincarnated in many forms to create a series of productive loops.

End of pipe – closing the stable door after the horse has bolted. Only the first step towards sustainability since eventually we should design problems out of the system, rather than trying to clean them up.

Factor 4, 10 or 20 – reducing resource intensity (energy and materials) for a given outcome. To become sustainable the world needs to aim for Factor 10, the same results for 10% of the input. This means a bigger factor of improvement for developed countries, something like Factor 20.

Global warming – a commonly used term for ‘climate change’ (see above). ‘Global warming’ suggests a universal rise in temperature, whereas some parts of the globe may become cooler as the knock-on effects of climate change kick in. Hence, ‘climate change’ is probably more accurate in that it allows for a range of effects, including extreme weather events such as flooding, hurricanes and drought, and some regions potentially becoming cooler.

Greenhouse gas – a cocktail of gases, of which CO₂ is the most well known, which can trigger a rise in average temperatures.

Heat gain – the way a building heats up such as absorbing sunlight, creating a need for cooling. By using pale surfaces, trees, natural lighting, or other heat reflecting means, heat gain can be reduced and with it the cooling load.

High performance buildings – a synonym for sustainable building, recognising that sustainable design leads to buildings using fewer resources and less energy with greater well-being and productivity.

Industrial ecology – (re)designing industrial systems to act like ecosystems in a closed loop manner. This allows the ‘waste’ from one industry or process to be the feedstock of another. Also known as ‘industrial symbiosis’.

Life cycle thinking or design – considering the whole impact of a product or process, not just the bits you see. This could include labour issues, the energy and water that went into production, transport implications, manufacturing, use and disposal. The aim is to extend the useful life of products and components, ideally creating a closed loop system. There are hundreds of tools in ‘Life Cycle Analysis’ or ‘Life Cycle Assessment’ which let you measure impacts of materials or products.

Micro-generation – generating power in situ, within a building or neighbourhood. As well as creating renewable energy, micro-generation provides resilience – lots of mini ‘power-plants’ mean large scale black-outs are less likely, and they are more elusive as terrorist targets than big power plants.

Natural ventilation – fresh air and comfortable temperatures without machinery, relying rather on the physics of air flow and heat to create buildings that self-regulate.

Negawatts – when buildings become self-sufficient in energy, anything they produce that is surplus to their needs can be fed into the grid, so-called negawatts, that is, using a negative amount of energy.

Passive ventilation – similar to natural ventilation, passive meaning without machinery.

Rebound effect – making something more efficient can sometimes lead to increased consumption overall. For example, if people know that light bulbs are energy efficient, they may be more likely to leave them on, creating greater energy consumption than conventional bulbs. Therefore worth monitoring the use of more efficient systems.

Resource productivity – yielding more performance or benefit per unit of material or energy input.

Sustainable – all systems (including social, environmental, economic and cultural) flourishing harmoniously without waste, degradation, suffering or superfluity. The best of all possible worlds, but at least partially attainable if we apply the grey matter.

Whole building design – the integrated approach to making buildings more sustainable, allowing you to optimise the system and so simplify the parts of it.

Zero waste – an explicit goal of some organisations, together with 'zero emissions'.