9

SUSTAINABLE ARCHITECTURE

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Introduction

This chapter outlines the characteristics of so-called sustainable architecture citing examples from current practice. 'So-called' because it should be established from the outset that it is very rare to find a truly sustainable building. Nearly every act of building damages the environment in some way: in excavating the site, the existing ecology is harmed; in moving materials, transport routes are polluted by noise and emissions; in providing heating or cooling, carbon dioxide is often released. All we can say with a modicum of certainty is that some buildings are more sustainable than others.

Contrary to popular perceptions, the greenest buildings are not usually those that wear their colour on their sleeves, in the form of solar panels, wind turbines or other *eco-bling*.[1] No, the most environmentally friendly buildings are usually quiet and unassuming in exploiting daylight, using natural ventilation and embracing other passive forms of environmental control. In this way they reduce the demand for energy that would otherwise be needed to run them on an hourly, daily and annual basis, minimising carbon emissions during their lifespan. In addition to the environmental and cost benefits, reducing demand for energy in buildings has three direct effects: (1) eliminating or requiring smaller mechanical service systems; (2) making the buildings themselves more robust and resilient, in that they require less heating or cooling; and (3) reducing the number of new power stations required to generate electricity.

The definition of what constitutes sustainable architecture will vary according to our perception of the environment to be sustained. The assumption here is that it is the broader global environment that is to be protected, and that the threats are those outlined in the Bruntland Report of 1987 (WCED 1987), as elaborated by Agenda 21.[2] Among a raft of aims, the need to protect biodiversity, to conserve resources and to limit pollution are put to the fore. More recent environmental summits have focused on the most pressing problem, which is to limit atmospheric carbon emissions. More-sustainable buildings are characterised by their lower consumption of energy, materials, water and other resources and by their use of materials that have lower negative impacts on the natural environment.

Sustainable architecture is not a new phenomenon. Turn the clock back two hundred years – before the era when fossil fuels became available widely, cheaply, and in large quantities – and you find buildings that exhibit many of the characteristics that we see in the more-sustainable buildings of today. Societies in the past operated within the capacity of the local environment to provide resources for the construction and operation of new buildings; and their environmental impact was generally felt locally (Fieldson 2004: 27). Look further back in time or further afield, to the multifarious forms of vernacular architecture that have evolved over centuries around the world to suit particular climates and cultures, and you can discover unique solutions in different indigenous communities that not only improve comfort in hostile environments, but that are beautiful in their own right (Rapoport 1969).

From this root, in vernacular buildings constructed prior to the Industrial Revolution, and from its other root in the counter-culture movement of the late 1960s, sustainable architecture has now grown to become mainstream. Building owners, architects, and even contractors, now vie to be recognised as the greenest or the most environmentally friendly.

Despite this, the claims made for sustainability by corporations and individuals are often poorly founded or exposed as *greenwash* – of suspect validity. Independently devised and administered assessment schemes have therefore been established to test environmental claims against a common code that both precedes and drives changes in legislation. Sustainability objectives are now entrenched in building regulations and government directives. The voluntary environmental assessment methodologies, such as BREEAM (Building Research Establishment Environmental Assessment System) and LEED (Leadership in Energy and Environmental Design), on which the new legislation is founded, are used to calibrate sustainability indicators against a set of common scales (BRE 2014) Although Environmental Assessment has now become commonplace, it is not very flexible. The methodologies employed do not tend to encourage the kind of innovative practice that is characteristic of the most advanced sustainable design, and which, by its very nature – at the vanguard of a rapidly evolving field – goes beyond the status quo.[3]

At the end of the chapter I probe possible new directions for sustainable architecture. Future scenarios must be seen in the context of the gauntlet set down by climate scientists, who assert that, in order to stabilise the climate, carbon emissions must be reduced by 80–90 percent compared to 1990.[4]

The challenge is huge and daunting, and it is very far from clear that the target will or even can be met. However, with the construction and use of buildings accounting for 50 per cent of all carbon emissions, there is little alternative but to try and rise to the challenge (BIS 2010) Acknowledging that most of the buildings standing in 40 years time have already been built, what is clear is that adaptation and retrofit must form a central part of the overall drive in creating the low carbon buildings of the future.

The roots of sustainable design

In exploring possible models for the low energy buildings of the future, architects have been looking to the past, both in the self-conscious tradition, as well as to vernacular architecture around the world. Among the vernacular body a large vocabulary of strategies has already evolved to deal with various environmental conditions in different regions, tuned to local climate and culture (Rapoport 1969; Behling and Behling 2000).

In the hot dry region of the Middle East, thick-skinned buildings with small windows are tightly packed together, forming narrow streets and courtyards, to prevent the sun from beating down on them. The earth or masonry walls provide high thermal mass, which stabilises the temperatures inside, so that they are lower than the ambient external temperature during the heat of the day. Plants and fountains in courtyards further contribute to improving comfort by lowering the air temperature through evaporation (Oliver 2003).

In marked contrast, in the tropical climate of Indonesia, houses are raised on stilts with perforate walling of open louvres. This maximises the potential for breezes, which are the only respite from the hot humid atmosphere. Light-coloured roofs with large overhangs reflect or exclude sunlight, which would otherwise exacerbate the uncomfortable conditions inside (Pearson 1989: 69).

In Scandinavia, houses are optimally buried into a south-facing slope, to protect against the cold north winds, and have windows facing south to bring in warming and welcome sunlight. Thick walls and roofs of thatch or turf help to insulate the interior from the bitter cold during the long winters (ibid.).

The lessons learned in obtaining comfort in climatic extremes can be applied to new buildings in various regions. In temperate zones, for example, which have to cope with cold winters and hot summers, the passive solar strategies inherent in the Scandinavian example can be adopted in winter, by using thick insulation and south-facing glazing. For summer comfort, the high thermal mass materials of the Middle East example can be reinterpreted in concrete to stabilise temperatures, and with solar shading to exclude sunlight. Some examples later help to illustrate the possibilities.

Designers today, however, must be careful when adopting or adapting vernacular modes of construction. First, though methods of environmental control in traditional buildings certainly improved conditions internally, they would rarely achieve the standards of comfort that we expect today. Traditionally, people in cold climates still needed to dress in thick clothes and their houses, or part of them only, would be heated for limited periods. Similarly, buildings in hot climates would not achieve the low temperatures provided by air conditioning systems today. Traditional vernacular buildings in general were often very energy-inefficient by today's standards.

Second, the technologies that have evolved over many centuries in different climates and cultures, may not be easy to fully understand. Misunderstandings may arise because local modes of building are often informed by social, religious or practical factors in addition to the desire for comfort in a hostile environment. Social hierarchies and ritual customs, or religious practice, can require particular orientations or room arrangements and so determine the building layout (Rapoport 1969; O'Cofaigh 1996 et al.: 1–2). The limited availability of construction materials, or traditions employing particular building crafts and skills, can often trump a strategy that might otherwise prioritise comfort in response to adverse climatic conditions.

Despite these limitations, vernacular buildings also exhibit other characteristics that we associate with some enthusiasts building sustainably today; they are usually built of natural materials obtained in the locality, which are often renewable, biodegradable, and non-toxic – for example thatch or timber or clay – and use the skills of the owner or local community.

In the 1950s, in the United States, Victor Olgyay, together with colleagues at Princeton, formalised the science of analysing climates, and developed methodologies for designing buildings that respond to climate in a positive way – taking advantage of its beneficial effects and expressing the systems of environmental control in the architecture. Some of these methods were published in his seminal book *Design with Climate* (1963). His approach marked a distinct change from the prevailing 'design against climate' approach, which used energy-hungry air-conditioning or heating systems to fight against the ambient temperature within glass buildings designed in the International Style, whatever the region or climate.[5]

The more astute colonial builders also realised that exporting building typologies that had evolved in Europe and transplanting them to Africa and India did not produce the most comfortable buildings! At the Building Research Station (BRS) in the UK, founded in 1921, a colonial liaison section was established in 1948, later becoming the tropical division. Like Olgyay in the USA, they began to bring scientific method to the tasks that indigenous people had understood over centuries through intuition and tradition. BRS later evolved into the Building Research Establishment (BRE), the body that has pioneered the standardisation of environmental assessment internationally.

The functional lessons of environmental control and material use are only part of what vernacular architecture can teach us. Bernard Rudofsky was one of the first to awaken Western architects to the poetic beauty of an architecture without architects (1964) and to building traditions that had developed unconsciously, in contrast to the self-conscious methods employed by professional architects.

By the late 1960s, a counter-culture movement had emerged that challenged the established order on several fronts: political, cultural, social, and environmental. Environmental concerns were triggered by signs of degradation caused by the untrammelled use of chemicals (Carson 1962), the destruction of natural habitats and perceptions of the increasing scarcity of resources (*The Ecologist* 1972).

The environmental strand of the movement began to envisage models of living that would cope with the uncertain future that seemed to be round the corner. With shortages of oil a realistic prospect and shortages of most raw materials predicted (Ward and Dubois 1973), incorrectly as it happened, many thought that the solution lay in becoming self-sufficient – in energy, food, and other resources. Those that were well prepared would survive the feared apocalypse that could occur at any moment. The autonomous house emerged as one model to achieve this. The house on its own plot would be self-sufficient in energy for heating and hot water, for cooking fuel and food and water. The building, its systems and the land would provide all the everyday needs of a family. It was a dream (or nightmare depending on your point of view) that was attempted by a few pioneers.

At Cambridge University in 1971, Alexander Pike created the concept of the Autarkic House, a prototypical autonomous house, with solar heating, wind turbine on the roof to generate electricity, and digester to convert sewage to methane gas for heating and cooking (Vale and Vale 2000). Working on Pike's team, Brenda Vale began to publish academic papers setting out the technical specifications for the autonomous systems that would comprise the required technology. In 1974 she and her husband Robert published their seminal book *The Autonomous House*, but it took nearly twenty years before they implemented the ideas in practice – in their own home in Southwell, Nottinghamshire – the first autonomous house in the UK. In the USA, Steve Baer built a solar house – comprising polyhedral 'zomes' – with recycled oil drums placed behind a glazed wall that used the sun to heat water.

These early pioneers inspired some enthusiastic followers around the world from the mid-1970s onwards. These included Lucien Kroll in Belgium, Architype and Feilden Clegg in the UK, Thomas Herzog and Gunter Behnisch in Germany, Sim van der Ryn in the USA, and Glen Murcutt in Australia. Some common principles of sustainable design that began to emerge from this disparate group of architects are summarised in Table 9.1.

Current practice

It has taken some 40 years since the pioneering work of the Vales and others to arrive at a point now when environmental requirements are commonplace criteria within every architect's brief. Sustainable design has moved from its associations with 'alternative' lifestyles in the 1970s to a niche professional area in the 1980s and 1990s, to become mainstream from the turn of this century onwards.

Table 9.1 Five principles of sustainable design

1. Working in cycles, like natural ecosystems, to minimise or eliminate waste and cause minimal damage to natural ecosystems —in contrast to the linear processes characteristic of the industrial revolution
2. Economy of means – using as little material as possible
3. Materials selected preferentially to be: (a) least toxic; (b) least processed; and (c) least travelled, especially if heavy (after Robert Vale)
4. Passive design – getting the building fabric itself to do most of the work in controlling temperature and ventilation
5. Designing buildings that people want and appreciate and understand – involving the user in the design, construction and post-completion stages.

Leading architects and engineers in the field, such as Thomas Herzog, Max Fordham and Ken Yeang, are of one view regarding the starting point for sustainable design: that the primary and initial focus should be for the building itself to control the internal environment, passively (Bothwell 2011: 70). Passive environmental control techniques, that in the past were the only choice for improving comfort, are now being relearned.

The headquarters building for Wessex Water near Bath is a showcase for these passive strategies (see Figure 9.1). In office buildings the major energy uses are for lighting and cooling. Bearing this in mind, the architect Rab Bennetts has very carefully choreographed the building elements to maximise the free use of natural light and to keep the building cool (Hawkes 2000).

The office wings are kept narrow and have high ceilings, to bring daylight deep into the interior. The ceilings are painted white and are uncluttered so as to efficiently reflect natural light inwards. External walls are proportioned to optimise the ratio of glazing to solid insulated elements, such that the total energy cost, balancing heat losses and light gains through the glazing, is minimised.

In addition to admitting high levels of daylight the shallow building depth assists with natural cross ventilation across the office wings. The exposed solid concrete elements in the ceiling, which form the structure of the floor above, act as a thermal flywheel, absorbing heat gains from people and computers during the day, and releasing them at night when cool outside air is passed underneath to purge them (Hawkes 2000).

Unwanted solar gains are particularly problematic in office buildings because they exacerbate the high *casual* heat gains arising from people, light fittings, computers and other equipment. Until recently this overheating problem would have been simply and swiftly banished by the installation of an energy-hungry air-conditioning system. But the Wessex Water building is carefully designed to avoid this. It is orientated with the main façades facing north and south. This enables the south façade to be easily shaded by shallow overhangs and simple louvres. The north façades, which receive sunlight only in the summer, are shaded by a line of deciduous trees planted parallel to the building, that obstruct the low altitude sunlight in early morning and late afternoon. In winter when the trees have shed their leaves, daylight from the sky can easily penetrate past the bare branches to illuminate the interior.

In this building, a very careful consideration of building form (narrow plan with high ceilings), orientation (east–west linear wings), materials (concrete ceilings, light coloured), and façade proportions (glazing vs. solid) all combine to reduce energy use and increase comfort.

Although exemplary in passively controlling the internal environmental conditions, Bennetts Associates go further than this in their efforts to minimise the overall environmental impact. They have selected a combined steel and concrete floor structure, which ensures that the materials are lighter than on earlier projects which employed only solid concrete, thus reducing the

Figure 9.1 Wessex Water building, Bath, by Bennetts Associates Architects: South elevation

embodied energy in both manufacture and transportation. Moreover, recycled railway sleepers have been crushed to provide the aggregate for the new concrete ceiling elements. Bath stone – locally sourced to minimise transport impacts – forms the walls of the western wing of the building that houses a social 'street' for the employees. Further environmental measures include recovering rainwater for reuse, using solar panels to heat water, and selecting indigenous plants for the landscaping to encourage local fauna.

Many of these features and characteristics are not overtly green, and most people on seeing it would not immediately recognise this as an environmentally sound building. Table 9.2 presents the characteristics of sustainable buildings. Although it looks much like any other office block, albeit a very elegant one, when it was completed in 2000, it was lauded as the lowest energy office building in the UK.

Table 9.2 Typical characteristics of sustainable buildings

- Low energy consumption in use (well insulated, passively controlling temperature, light and ventilation)
- Low embodied-energy materials used in construction
- Low environmental damage materials used in construction (low toxicity, renewable materials, …)
- Maintaining and enhancing biodiversity
- Reducing the need for travel (green travel plans, near transport hubs if large numbers of people using building)
- Conserving, recovering and reusing water
- Drainage treated on site using natural processes (reed beds)
- Long lived (beautiful, popular and/or pleasant places to live and work, that people want to keep, durable)
- Multi-use (buildings that combine various functions and/or that can be used for longer period of the day, week, year)

The costs of constructing a more-sustainable building can be little more than building a conventional one, and sometimes even less, depending on the base case against which it is compared (Rehm and Ade 2013). A survey of buildings in California has reported that the typical construction cost premium for building green is 2 per cent but that the financial benefits are almost ten times this premium: 'The financial benefits of green buildings include lower energy, waste, and water costs, lower environmental and emissions costs, and lower operations and maintenance costs and savings from increased productivity and health' (Kats 2003: 85).

However, the calculated benefits are those that accrue to the people of California as a whole, rather than just the owners of buildings (ibid.). In the UK, the additional costs of constructing the most exemplary sustainable buildings are calculated at between 1 and 7 per cent, depending on the building type. In the most sophisticated building types, such as healthcare buildings, the premium is much lower (Cyril Sweett and BRE Trust 2005).

The social street in the Wessex Water example represents a further characteristic of the most sustainable buildings. Buildings that are loved or appreciated by people, where users have a role in the design or buildings that 'belong' in some sense to them, and that are comfortable to be in, are likely to be well-maintained and cared for into the future.

The BedZed community in south London was a test-bed for many sustainable design principles and technologies. It combines two distinct building types – housing and offices – to achieve the optimal passive design for each and to enable people to live close to their work. Arranged in rows aligned east–west, the houses are located on the south side of each block with large windows to receive sunlight in winter. The offices nestle along the north sides, to protect them from solar gains, but gain plenty of daylight from north-facing rooflights (Long, 2001).

At Freiburg, in southern Germany, a similar community is emerging in the Vauban district. The city itself has ambitious objectives for public transport and low energy buildings. The solar community and *solar-ship* development combines housing with commercial uses to achieve a symbiotic relationship between the two – the housing benefitting from solar gains, and the commercial uses from daylight (see Figure 9.2). Overall its highly insulated passive solar houses are net exporters of energy – generating electricity from the photovoltaic panels on their roofs. The residents participated in the design of the housing so achieve a high sense of 'ownership' (Guzowski 2010).

This public-spirited approach can also be extended to tall buildings. Norman Foster challenged the established typology of the skyscraper – normally a stack of identical office floor plates – with his tower for the Hong Kong and Shanghai Bank in Hong Kong in 1985. First, the

Figure 9.2 Solar Community and Solar-ship mixed use development in Freiburg, by Rolf Disch Solar Architecture

ground level was given over entirely to the public, with the building raised on columns so that people could wander under and into the building via escalators starting in the street. He introduced sunlight reflected off a giant mirror hung outside the building and then bounced this down the atrium space in its centre. His Commerzbank in Frankfurt was similarly innovative, incorporating sky gardens – multi-storey atrium spaces with trees and other planting – that bring natural light deep into the building, provide ventilation, and create interactive social spaces. The façades are doubled up to form a buffer zone between inside and outside, that pre-heats air in winter and removes excess heat in summer, avoiding the need for full air conditioning.

Some of the ideas for reducing the need for air-conditioning, which evolved in these earlier skyscraper projects were incorporated in the design of the 'Gherkin' – the office building for Swiss Re in London. Designed to be naturally ventilated, the tower has spiral atrium spaces winding their way round the building. Opening windows (a rarity in tall buildings) allow fresh air to directly enter the atrium spaces and thence to the adjoining offices (Ritchie 2004). Unfortunately the tenants of the building are so sensitive to the possibility that others might overhear their corporate secrets through the open windows, that they do not use the natural ventilation systems and have installed air-conditioning instead!

Building users are the one factor that architects and designers cannot control, yet they generally account for the huge discrepancy between energy predictions and actual consumption levels. With the increasing complexity of building servicing systems and controls, there is much evidence that even building managers do not understand how many buildings are supposed to work! A hiatus often occurs between the original design strategy and the everyday operation of the building.

Under 'design and build' contracts (popular with some clients), the concept architects and engineers are not involved in the detailed design, which is carried out by a range of often poorly coordinated sub-contractors, under the direction of a main contractor. Systems may end up competing against each other, so that automatic vents are opening to cool a building when the users turn up the thermostat. Surprising as it may seem, this type of problem is commonplace. The message to take from this is plain – keep the building as simple as possible, communicate clearly between all parties, and tell the users how to operate the building.

One approach that may help to address this problem is the Passivhaus standard, which is emerging as a new model for sustainable design. Originally developed for houses in the climate of northern Europe, it has now evolved to encompass any building type in any climate. Passivhaus emerged in Germany in the 1990s, following the exhaustive analysis of actual performance data on a large number of dwellings. The originators of the standard, Wolfgang Feist and Bo Adamson, sought to fully account for, and model, all the subtle variables that affect energy consumption. Passivhaus accounts only for energy consumption and human comfort, excluding all other environmental impacts (Cotterell and Dadeby 2012: 19). Nevertheless, it is increasingly being used as the benchmark against which other environmental standards are compared. Passivhaus buildings are very highly insulated, air-tight and have mechanical ventilation heat recovery systems (MVHR). These ventilation systems warm incoming air in winter using heat recovered from the vitiated air, and can be 80–90 per cent efficient.

Homes built to Passivhaus standards will incur much lower installation costs for the small heating systems that may still be required, but additional costs for the higher specification of insulation, windows and air-tightness. Net increases in construction cost are in the region of five percent, but can be balanced against far greater levels of comfort and very much lower fuel bills (ibid.).

Codes and methodologies

In response to wildly inconsistent environmental claims made by the building industry, Environmental Assessment (EA) systems have been established. The UK Building Research Establishment (BRE) launched the world's first environmental assessment system for buildings in 1990. The method, titled BREEAM (BRE Environmental Assessment Method), originally laid out guidelines for the evaluation of office buildings.

The BREEAM system endeavoured to embrace all environmental impacts caused by buildings. Its aims were: to mitigate the impact of buildings on the environment; to enable buildings to be recognised according to their environmental benefits; to provide a credible label for buildings; and to stimulate demand for sustainable buildings (BRE 2014).

Environmental issues are only included in BREEAM if they meet specific criteria. They must be significant and offer worthwhile reductions in environmental impact, be assessable at the relevant stage in the building's life, be based on scientific evidence wherever possible, exceed the demands of law and legislation, and be achievable.

One of the objectives of environmental assessment is to challenge the market to provide innovative solutions that minimise the impact of buildings. This objective and the criterion that the system must exceed legislation create paradoxes. If the standards set have any validity, then they will, before too long, be incorporated into legislation (as they have been with respect to housing in the UK) and the method will therefore no longer surpass those required by regulations. The objective to stimulate innovative solutions is difficult to achieve. By its very nature, the method, within each specific issue, has to describe particular standards, targets and criteria for verification. This process can only be designed when the construction technologies employed are established, tested, and familiar, i.e. when they are no longer innovative.

Table 9.3 BREEAM categories of environmental impacts included in the Code for Sustainable Homes (CSH)

Category	*Points available*
Energy and CO_2	36
Health and well-being	14
Ecology	12
Management	10
Water	9
Materials	7
Waste	6
Pollution	3
Surface water run-off	2

Note: These categories have varied over the evolution of the method and vary according to building type.

A case arises when evaluating the use of straw, an increasingly common building material. Straw bales are a low cost, very low impact building material, that use an otherwise waste material, lock up carbon dioxide, and provide high levels of insulation. However, they are not listed in the schedule of BREEAM-approved materials, so cannot currently contribute positively to a rating.

For ease of assessment and to prioritise certain fields, each issue is placed within a particular category (see Table 9.3). These categories have changed as the system has developed and as it has been applied to different building types. Each issue is assigned a number of points and each category is weighted differently, depending on its perceived importance. For example, the category Energy and CO_2 emissions is weighted far more strongly than those for Waste or Ecology. This reflects the consensus on what is the most pressing environmental problem to solve – global warming. Because regulations are being improved in the wake of environmental assessment initiatives, the bar for environmental assessment systems themselves is also being raised. Thus, a rating of, say, Excellent today is much more difficult to achieve than the same rating ten years ago.

In the United States, the LEED system has evolved with a scale that has Platinum as the top rating. Unlike BREEAM, which is validated and controlled by a charitable trust, LEED (Leadership in Energy and Environmental Design) is managed by a trade association, the Green Building Council. The Green Building Council comprises architects, engineers, contractors and others in the building industry. In Australia they use GreenStar, and in Singapore the BCA Green Mark system. International versions of BREEAM and LEED are also validated for different countries around the world.

All EA systems use life cycle assessment (LCA) methodologies that take into account the environmental impacts that occur at all stages of a building's life, from construction, everyday use and maintenance, to refurbishment and eventual demolition. This is sometimes referred to as 'cradle-to-grave' analysis. However, Braungart and McDonough (2002) have extended this concept to 'cradle-to-cradle' such that the materials at the end of the building's life are considered not to be waste materials for recycling but valuable resources that could be 'upcycled' to achieve a higher value in their next incarnation. Some materials, such as timber flooring boards, can be clamped into position without nails, such that they can be simply disassembled to be reused for a future project (Liddell 2008).

Environmental assessment systems have done much to encourage consideration of sustainability criteria and to set standards against which achievements can be measured and projects compared. Many clients and their design teams have been encouraged to have their buildings assessed in the knowledge that this raises the prestige of their organisations. The Wessex Water building achieved a BREEAM Excellent rating when it was completed in 2000 and the Singapore Library by Ken Yeang achieved BCA Green Mark Platinum rating in 2005.

Ken Yeang is an architect who has been at the forefront in exploring new directions for green architecture over several decades. His Roof-Roof house of 1985 used the building elements to control the climate. It is named after its double roof, the outer one of which shades the lower terrace from the heat of the tropical sun, so that it can be used for recreation next to a swimming pool. The upper roof is perforated with louvres which are specially angled and orientated to allow through the low morning sun but to exclude the searing midday and evening sun. The pool, located on the east side to face the prevailing winds, also cools the air, through evaporation, before it enters the building. Walls on the south side direct wind to cool the dining area (Hart 2011).

An air-cooling pool is also deployed on the roof of his Menara Mesingiaga tower in Kuala Lumpur. Cylindrical in form, the building facades are partially covered in solar shading panels, which flow round the building in a pattern that follows the sun's path around the sky. The lift tower is located on the south side to shade the building. The upper louvred roof canopy allows for future photovoltaics and the stepped façade provides terraces for people as well as shading for the floors below (ibid.).

In spite of these pioneers, and the stimulus provided by EA methods, when looking at the building stock as a whole, progress has been slow and incremental. The overall environmental impact of buildings has been little affected and it is becoming apparent that fundamental and systemic changes are needed to achieve the carbon reductions that are necessary.

Future directions

Retrofit

One systemic change required will be the retrofit of the existing building stock, to raise its energy efficiency closer to current standards. Most of the buildings that will exist in 2050 were constructed prior to 1970, when energy efficiency standards were low. As well as bringing environmental benefits for society at large, with lower carbon emissions, retrofit will improve comfort for building users and reduce energy bills – a triple-win situation. However, to obtain the necessary reductions in CO_2 emissions 'deep retrofit' solutions are required and the difficulties encountered in achieving this are significant.

Pioneering work has been done, some funded directly by governments, to assess the feasibility of rolling out retrofit on a wide scale. Despite some encouraging results in terms of energy reductions it seems unlikely that retrofit can meet the carbon targets set for the building sector. There are a great many 'hard to treat' properties – such as historic buildings where the appearance cannot be changed, or buildings that have physical restrictions which, for example, prevent the application of insulation materials – and that can only receive rudimentary improvements. The process of deep retrofits is often very disruptive, requiring occupiers to move out during building works, adding the rent for temporary accommodation to the very high cost of construction works. Costs for whole house retrofits are predicted to come down to between on average £25,000–£30, 000 after experience has been gained, but these costs will take very many decades to recoup in terms of reduced energy bills.

The task is also gargantuan. In the UK housing sector alone there are 26 million homes, and if they are all to be treated by the year 2050, that will require them to be retrofitted at the rate of more than 700,000 per year. As this is seven times the rate that new houses are currently being constructed, it is questionable whether the building industry has the capacity to address the task, let alone the finance necessary to fund it.

Biomimicry

Integrated and holistic changes are beginning to emerge in the design of new buildings. One of the underlying concepts guiding sustainable architecture is that of biomimicry – modelling building designs on natural ecological systems. People have been inspired to copy natural examples from the earliest days. When the ecological design field began to emerge in the 1960s the technical means available to architects lacked the sophistication and subtlety to reflect the complexity of plants and animals. However, with the advanced computer software and manufacturing methods that are now available and our increasing understanding of biological systems, it is becoming possible to mimic the behaviour of some natural processes quite accurately.

As his œuvre has developed, Ken Yeang's buildings have become literally as well as metaphorically greener. Yeang's early ideas have evolved into a formally structured approach to architectural design founded on the concept of ecomimesis. Buildings, for Yeang, should not just be based on ecological principles or incorporate plant life, they should actually become 'constructed living systems' in their own right. Like naturally occurring ecosystems, they will produce no wastes, but recycle everything within a closed-loop system.

Yeang's new buildings now incorporate planting snaking up the facades. These form miniature green ecosystems of plants, insects and animals (Figure 9.3). A key requirement is that they must stretch continuously from the ground all the way up round the building, so that species, carefully selected to be compatible with indigenous ones in the area, can easily migrate. The vertical green eco-infrastructure is then networked into the green infrastructure of the city. The EDITT building shown here generates electricity, collects and purifies rainwater, and processes wastes into biogas and fertilisers (Hart 2011).

Zooming out to the larger scale of the city district, the concept of continuous productive urban landscapes (CPULs) has been put forward as a model for sustainable urban development (Viljoen 2005). Linear green corridors are created, using existing parks, vacant sites and street edges to form a continuous habitat for plants and animals. These corridors include water catchment reservoirs and waste treatment systems, cycle routes, leisure areas and allotments, all connected together and extending through the city.

CPULs are seen one solution to the high cost of food, particularly in poorer urban communities such as those in Cuba, where vacant city plots are converted into market gardens on a commercial basis. The land is tilled by hand and has a very high yield (ibid.: 153).

Food grown near to where people live cuts out the storage and distribution processes and transport that would otherwise consume fossil fuels. Perhaps more importantly, it brings people together into communities that might otherwise never have arisen – communities that work together to make compost, to plant seeds, and to harvest the crops and celebrate together when they have done so! These productive urban landscapes enhance the ecological value of cities, bringing in insects and birds and other fauna and flora. The heat island effect is also reduced by lowering temperatures in summer (ibid.).

Biomimicry is developing from the imitation of nature in formal terms, to the direct application of biological systems to control sunlight and generate energy in buildings. The

Figure 9.3 EDITT tower project, Singapore, by Ken Yeang

Source: T.R. Hamzah & Yeang Sdn. Bhd. (2014)

BIQ apartment building in Hamburg, which opened in 2013, uses algae in glass tanks on the south-facing façades to perform several functions. The algae-filled tanks restrict light penetration so act as a solar filters or solar shades (Figure 9.4). The system works by introducing nutrients and carbon dioxide, which is pulsed into the tanks at regular intervals. Algae is extracted on a regular cycle and fermented in a biogas plant which produces methane to power the building. Solar panels generate heat that is stored in brine-filled boreholes beneath the building, to be reused later (Wurm 2013: 90–95).

Conclusion

We have seen a variety of approaches to the design of a more-sustainable built environment. The trend has been away from the self-sufficient autonomous house with its hard technology *eco-bling* that pioneered the sustainable architecture movement, to the widespread adoption of passive design. This recognises the paramount importance of reducing the demand for energy in the first place. Only then, if at all, should *eco-bling* be added to supply energy, and even then it is more efficient to locate this in large arrays rather than on individual buildings.

The trend in now away from the design of the individual building towards a mixed-use and multiplex approach, identifying the mutually beneficial needs of different building types.

These kinds of symbiotic relationships characterise the more holistic strategies now being adopted for sustainable development in cities, where buildings and the urban landscape between them form a continuous system – a network of interconnected hard and soft technology elements. Biotechnology systems are beginning to offer many interesting solutions for energy supply, environmental control and waste treatments.

Systemic changes will be needed too in the way that we live and work in cities, so that we reduce the need for energy and resources, for travelling, and for heating and cooling our buildings, and for growing food. It seems possible that these changes will result in significant changes in lifestyles – to a more cooperative and community-based way of living – in contrast to the more individual lives that most in the developed world currently enjoy.

Some environmentalists have argued that individual small-scale efforts to reduce energy are pointless in the face of the threat of global warming. However, it is this author's view that in the battle to create the more-sustainable buildings of the future – and it will indeed be a battle, for the effort required will be comparable to waging a war – we will need to fight on all fronts at the same time. This is not to say that new avenues, in terms of technologies or strategies, will not open up, but we cannot depend on encountering a technological panacea within the short time that remains available.

How all this can be funded is beyond the scope of this chapter, but it seems likely that, although sustainable new buildings can be seen to pay for themselves, markets alone will have insufficient motive to invest in large-scale retrofit, due to the huge costs and lengthy payback periods involved. Government subsidies or incentives are likely to be the only way to significantly reduce carbon emissions from the currently existing stock, which will still comprise the majority of buildings in 2050. Decarbonising the electricity supply itself must also form part of the mix (DECC 2010).

We have seen that the route to a more sustainable architecture has been to a large extent a journey of rediscovery – rediscovering old ways of achieving comfort in hostile environments, using materials frugally, efficiently and simply, and employing technology only when it really helps and when people can fully understand it. Although new technologies are emerging that have extraordinary potential, we may well find that the past remains the best guide to our future.

Figure 9.4 BIQ building, Hamburg, by Arap, exploits algae in façade

Source: Arup Deutschland GmbH, Colt International GmbH and SSC GmbH)

Notes

1 Eco-bling is a term coined by Doug King to describe low-performing renewable energy technologies installed on buildings. The shortcomings of various technologies classed as eco-bling are discussed in Liddell (2008, 2013).

2 Agenda 21 is the plan agreed at the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. The Agenda 21 plan identified four primary areas for action: (a) the social and economic dimensions; (b) the conservation and management of resources; (c) strengthening major groups (children, youth, women, NGOs, local authorities, indigenous peoples; and (d) the means of implementation.

3 Rick Wheal, an engineer specialising in environmental assessment, at leading global engineering company Arup, has criticised BREEAM for being too inflexible. (2013).

4 The UK government target of 80 per cent reductions in CO2 compared to 1990 levels, is highly ambitious but reflects the level of change advised as necessary by a consensus of climate scientists and even so is still lower than that advocated by some scientists and environmentalists, who suggest that we need a reduction target of ninety percent or higher. See also: DECC (2010) *2050 Pathways Analysis*.

5 The International Style, which developed out of the Modern Movement in architecture, was adopted by a generation of architects who built glazed slab and tower blocks in all parts of the world, irrespective of the local climate. The movement was inspired by Mies van der Rohe and Le Corbusier. Le Corbusier at the time advocated a universal house for all climates: 'only one house for all countries, the house of exact breathing' ([1930] 1991), although he later adopted a more climate-inflected approach.

References

Behling, S. and Behling, S. (2000) *Solar Power: The Evolution of Sustainable Architecture*. London: Prestel.

BIS (Department for Business Innovation & Skills) (2010) *Estimating the Amount of CO2 Emissions That the Construction Industry Can Influence*. London: UK Government 10/1316.

Bordass, B. (2000) Cost and value: fact and fiction. *Building Research and Information*, 28, September 2000.

Bothwell, K. (2011) The architecture of the passively tempered environment In S. Lee (ed.) *Aesthetics of Sustainable Architecture*. Rotterdam: 010 Publishers, pp. 66–79.

Braungart, M. and McDonough, W. (2002) *Cradle To Cradle: Remaking the Way We Make Things*. New York: North Point Press.

BRE (2014) *BREEAM UK New Construction: Technical Manual* SD5076: 0.1 (DRAFT) – 2014, Watford: BRE Global.

Carson, R. (1962) *Silent Spring*. Harmondworth: Penguin.

Cotterell, J. and Dadeby, A. (2012) *The Passivhaus Handbook: A Practical Guide to Constructing and Retrofitting Buildings for Ultra-Low Energy Performance*. London: Green Books.

Cyril Sweett/BRE Trust (2005) *BREEAM: Putting A Price on Sustainability*. Watford: BRE Trust.

DECC (Department of Energy and Climate Change) (2010) *2050 Pathways Analysis*. London: DECC.

The Ecologist (1972) *Blueprint for Survival*. Harmondsworth: Penguin.

Fieldson, R. (2004) Architecture & Environmentalism: Movements & Theory in Practice, *Forum (Ejournal*), 6(1): 21–33.

Guzowski, M. (2010) *Towards Zero Energy Architecture: New Solar Design*. London: Laurence King.

Hart, S. (2011) *Eco Architecture: The Work of Ken Yeang*. Chichester: John Wiley and Sons.

Hawkes, D. (2000) The flow of ideas: Bennetts Associates in Bath. *Architecture Today*,113: 60–76.

Kats, G. (2003) *The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force*. Sustainable Building Taskforce.

Le Corbusier ([1930] 1991) *Précisions on the Present State of Architecture and City Planning* (English Translation). Cambridge. MA: MIT Press.

Liddell, H. (2008) *Eco-Minimalism: The Antidote to Eco-Bling*. 2013 (2nd edn). London: RIBA Publishing.

Long, K. (2001) BedZed: case study part one – green and pleasant land. *Building Design*, 1473: 12–13.

O'Cofaigh, E., Olley, J. and Lewis, O. (1996) *The Climatic Dwelling*. London: James and James.

Olgyay, V. (1963) *Design with Climate*. Princeton, NJ: Princeton University Press.

Oliver, P. (2003) *Dwellings: The Vernacular House Worldwide*. London: Phaidon.

Pawlyn, M. (2011) *Biomimicry in Architecture*. London: RIBA Publishing.

Pearson, D. (1989) *The Natural House Book*. London: Conran Octopus.

Rapoport, A. (1969) *House Form and Culture*. Englewood Cliffs, NJ: Prentice Hall.

Rehm, M. and Ade, R. (2013) Construction costs comparison between 'green' and conventional office buildings. *Building Research and Information*, 41(2): 198–208.

Ritchie, I. et al. (2004) Foster's 30 St Mary Axe Tower. *Architecture Today*, 149: 54–66.

Rudofsky, B. (1964) *Architecture Without Architects*. Albuquerque, NM: University of New Mexico Press.

Vale, R. and Vale, B. (2000) *The New Autonomous House*. New York: Thames and Hudson.

Viljoen, A. (2005) *Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities*. Oxford: Architectural Press.

Ward, B. and Dubois, R. (1973) *Only One Earth*. Harmondsworth: Penguin.

WCED (World Commission on Environment and Development) (1987) *Our Common Future (The Brundtland Report)*. Oxford: Oxford University Press.

Wheal, R. (2013) 'There is more to sustainability than a building's environmental impact: BREEAM doesn't go far enough: truly great buildings make society better by adding to the area'. *The Guardian* sustainable business blog, Available at: www.theguardian.com/sustainable-business/blog/sustainability-building-environmental-impact?CMP=twt_fd (accessed 13 December 2013).

Wurm, J. (2013) Developing bio-responsive façades: BIQ House —the first pilot project. *Arup Journal*, 48(2): 90–95.

Yeang, K. (2006) *Ecodesign: A Manual for Ecological Design*. Chichester: Wiley Academy.

Yeang, K. and Spector, A. (eds) (2011) *Green Design: From Theory to Practice*. London: Black Dog.