Sustainability as a Driving Force in Contemporary Library Design

BRIAN W. EDWARDS

ABSTRACT

The drive for energy efficiency arising from a growing awareness of the dangers of climate change is leading to new approaches to library design. The article explores the interaction between library architecture and sustainability by reviewing the many complex strategies employed for saving or recycling evermore scarce natural resources. Although the focus is upon energy consumption, the article also investigates how concepts of comfort and climate are changing under the impact of environmental sustainability. These topics are discussed mainly in the context of public and university libraries built over the past decade, with some reference to library designs still awaiting construction. The methodology is developed primarily through comparative case studies, exploring the approach to environmental sustainability under a number of headings drawn from widely employed environmental assessment methods such as BREEAM (Building Research Establishment Environmental Assessment Method), commonly employed in the United Kingdom and much of Europe; and LEED (Leadership in Energy and Environmental Design), the assessment tool frequently used to anticipate the environmental credentials of projects still on the drawing board in the United States and Asia. In many ways the architectural approach to the twenty-first century library is returning to the roots of the modernist library found in Scandinavia with its emphasis upon high levels of daylight, natural materials, social harmony, and contact with nature.

Concerns over climate change and the consequent drive for energy efficiency is leading to new approaches to the design of libraries and the reshaping of existing ones. Greater attention is being paid not just to fossil
fuel energy consumption but to a wider range of environmental and ecological issues. In many ways the architectural approach to the twenty-first-century library is returning to the roots of the modernist library found in Scandinavia with its emphasis upon high levels of daylight, natural materials, social harmony, and contact with nature.

The article explores the interaction between library architecture and sustainability by reviewing the many complex strategies employed for saving or recycling evermore scarce natural resources. Although the focus is upon energy consumption, the article also investigates how concepts of comfort and climate are changing under the impact of environmental sustainability. These topics are discussed mainly in the context of public and university libraries built over the past decade, with some reference to library designs still awaiting construction.

The methodology is developed primarily through comparative case studies, exploring the approach to environmental sustainability under a number of headings drawn from widely employed environmental assessment methods such as BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design). BREEAM is commonly employed in the United Kingdom and much of Europe, while LEED is the assessment tool frequently used to anticipate the environmental credentials of projects still on the drawing board in the United States and Asia. Both are beginning to be used to steer evolving designs for libraries toward greater sustainability.

A typical example is the new library at Aberdeen University, designed by the Danish architectural practice of Schmidt Hammer Lassen (fig. 1). In achieving a BREEAM excellent rating, this library is generously daylit with solar gain and winter heat loss limited by the use of high performance glazing and an active facade. Added to this, the library roof is used not only to generate electricity (by employing photovoltaic panels) but also to collect rainwater to flush toilets. This library is typical of the increasing impact that environmental accreditation is having upon design.

The prerogative of sustainability is altering the design of new libraries and placing existing ones under ever greater environmental scrutiny. Hence the needs of library staff and users, on the one hand, and the storage of books and their integration with digital media, on the other, are having to adjust to the new meta-narratives of carbon accounting and global warming. The physical dimensions and architectural qualities of library space are increasingly dictated by demands to reduce energy flows, with consequent adjustment to embrace new environmental technologies.

Just as the approach to the design of offices and schools is being modified to reduce their carbon footprint, so too with libraries. A key argument in this article is that sustainability is altering typological assumptions as well as detailed architectural approaches, leading to libraries that offer greater user satisfaction and hence are better places to read, meet friends,
or study. In this positive view it is posited that environmental sustainability provides the opportunity to revitalize the design of public libraries and to transform them into structures worthy of their place as carriers of environmental messages in text and built form. Concerns over energy efficiency in particular are encouraging architects to rediscover the environmental approach that underpinned early modernist libraries, particularly those in Scandinavia. This, coupled with the ideals of social sustainability, is leading to a new generation of library buildings where public space for gathering and private space for reading is combined within attractive airy structures.

**Design Quality, Sustainability, and Environmental Conditions in Libraries**

The value of good environmental design is often overlooked by those who procure library buildings and draw up the brief. Yet high environ-
mental conditions can make a big difference to the perception of the library and, by extension, to the body that commissioned it, whether it be a municipality (public library), a national government (national library), or a university (academic library). Excellence in design is not, however, easy to measure especially in advance of construction. However, it is now widely accepted that the quality of environmental design affects the attitudes and behavior of library staff and users, particularly in areas such as productivity and concentration levels. There are some pointers that could be employed such as making sure that

- energy efficiency is a major factor in the overall design and in the interior library spaces;
- the building is connected well with public transport and provides good facilities for those who arrive on foot or by bicycle;
- the library is well lit and naturally ventilated, and daylight is available in all reading and study areas;
- acoustic quality of the different spaces has been addressed, particularly in open plan and atria-based libraries;
- potential adverse conditions such as solar glare, overshadowing, and traffic noise have been resolved;
- there are views out onto attractive areas, particularly those with greenery;
- interior air quality is moderated by incorporation of interior planting;
- there are views within the building that promote use legibility and aid navigation through complex library facilities.

The quality of design of civic buildings, such as libraries, affects the choices made by people in the facilities they use and more widely in where they choose to live or work (CABE, 2006, pp. 4, 15). These choices are increasingly influenced by the meanings and values being communicated through sustainable architectural design. Since the main source of man-made carbon emissions follows the burning of fossil fuels (for which over 40 percent are consumed within the building sector for heating, lighting, and ventilation), libraries have their role to play in mitigating global warming and, equally importantly, in sending the message of environmental care through good ecological design. Where BREEAM or LEED are employed, the subsequent library is likely to have a smaller environmental footprint than otherwise. Since libraries, like schools, have the ability to change attitudes through architectural design, architects and their clients need to ensure that sustainable design is visible particularly in the main public spaces of library buildings.

Increasingly, there is an expectation that daylight, controlled sunlight, and fresh air should be provided in all or most public parts of the library. This may be on the top floor where the café is provided, in a central atrium, or in study rooms around the edge. A number of surveys have
highlighted the importance attached to more natural conditions inside buildings, and there is increasing evidence that daylight in particular affects the ability to concentrate, especially at the interface between paper and digital media (Baker, 2009, p. 51). Hence reading rooms in particular need to be well lit but without the problems associated with solar gain. This results in reading rooms facing north as an ideal orientation, and where otherwise, extensive solar protection is needed.

Libraries as Carriers of Environmental Messages

Image is important to library design, and few images today carry more public acceptability or authority than an environmental one. Increasingly public libraries and learning resource centers on university campuses are expected to display best practice in the area of sustainable design. This allows the library to carry the green message into neighborhoods and onto academic courses. Hence sustainability is frequently incorporated into the brief for the design of new libraries and where it is not, architects and engineers have a duty to seek to reduce the carbon footprint of their designs.

The role of the library here is important as it stands for knowledge dissemination and intellectual discovery—and nowhere is this more pertinent today than in the arena of global warming and sustainability. It is no accident that many recent public libraries, such as at Brighton in the United Kingdom, designed by Bennetts Associates and in Scandinavia by Schmidt Hammer Lassen (fig. 2), have innovated in the area of energy efficiency. Here green technologies have been visibly displayed in order for the building to carry the message of sustainable design into the community and thereby teach through the building rather than just the books. This issue of wider citizenship learning is a key characteristic of library buildings whether in towns or on university campuses. In this the modern sustainable library begins to engage with the Nordic social democratic library tradition with its blending of art and nature, society and technology (Dahlkild, 2009, pp. 72–74).

Like all public buildings, libraries have a major impact on the environment. This extends from the energy used for heating, lighting, and ventilation to energy consumed via computers and in transport reaching the building. In addition, a large amount of water is consumed, and libraries have a big impact on biodiversity via the materials used in construction. Energy consumption is not the only issue, but it is often the driver in terms of legislation and public image. The twentieth century saw the demise of natural energy systems in favor of mechanical plant and imported energy. This resulted in deeply planned libraries that were dependent upon air-conditioning and artificial lighting. In these libraries the bulk of energy was used keeping the building cool because of the overdependence on artificial lighting. The twenty-first century appears to be revers-
ing this trend, and many former library buildings are being sliced open to allow daylight and ventilation to reach into their core. This improves interior conditions psychologically as well as saving considerable sums of imported energy.

The subject of sustainable design is a broad one, but in the context of libraries, there are a number of specific issues to consider.

Energy Usage and the Library Environment
The bulk of energy consumed in library buildings is to heat, light, and ventilate the interior spaces. Libraries also consume significant levels of energy to power computers and other forms of multimedia. So libraries are high-energy users and should seek to generate their own power (through photovoltaic panels or ground-source heating) wherever feasible. To achieve a low carbon footprint, the library architect needs to maximize daylight and opportunities for natural ventilation, to exploit
solar energy for wintertime heating and summertime stack-effect cooling, to control excessive solar gains and internal glare, and employ construction materials that have low embodied energy and high recycling potential. These are demanding technically, but when combined with modern library functions, the resulting building becomes a place of distinction, physically and socially.

Libraries differ from other building types in their energy profile. Typically a modern office building uses about 30 percent of its total energy consumption for electric lighting. However, in a public library the lighting figure can approach 45 percent. If electricity use is high, the heating load is often lower than in comparable buildings. This is because of the accidental heat gains from lighting and other equipment, and from the high level of people occupation in libraries. So a key principle of library design is to maximize interior daylighting levels and to consider carefully the consequent interaction between lighting, comfort, ventilation, and heating. One trend evident in today’s libraries is the use of highly glazed facades, necessary to reduce the use of electric lighting and hence heat buildup. This is evident in the Brandenburg University Library at Cottbus in Germany, designed by Herzog and de Meuron, and the Seattle Public Library by OMA (fig. 3). Both have facades that are extensively glazed but include large atrium spaces for internal ventilation. Where modern libraries are not wrapped in solar-controlled glass, they still remain extensively glazed, with typically the ratio of glass to solid panel approximating 50 percent. One consequent benefit of the open and transparent library is the way it signals that libraries are for people and not just for books.

The problems of overheating and poor energy use have been overcome by using double-skin glass facades. This technology provides the best of two worlds—that of maximizing daylight and that of using waste heat for cooling in the winter and for ventilation in the summer. The double façade offers the library the further benefit of acoustic screening of outside noise. Although double facades are technically complex, they offer better control of heat and light than orthodox facades. In large and prestigious libraries, such as the new wing of the Royal Library in Copenhagen, designed by Schmidt hammer Lassen, the cost is justified by the refined conditions achieved. However, as energy costs rise and carbon taxes are implemented, such technologies will become more commonplace.

A related trend is the use of exposed concrete in the structure of libraries to stabilize temperatures (using thermal capacity) and provide balance between the fabric of the building, lighting levels, and associated environmental systems. A good example is Alexandria Public Library in Egypt, which achieves a high-quality interior environment without high levels of imported energy by giving attention to lighting, natural ventilation, and thermal capacity (fig. 4). This equation is a major driver in design where heavyweight structure (for books) is combined with lightweight enclosure (for readers) to produce an attractive and dynamic library interior.
Energy conservation can also be achieved by ensuring the building is well insulated, airtight in construction, and uses such things as sensors to prevent artificial lights being employed when there is nobody present. High thermal mass also helps reduce energy consumption, particularly if the effects of transparency sought elsewhere for aesthetic delight can balance the needs of books and readers. Much can be achieved at little or no extra cost. Simply reducing the footprint of the building to the dimensions needed for natural light to penetrate the full depth of the interior can achieve considerable energy savings. Similarly the employment of atria and roofs that incorporate glazing can help with energy efficiency, especially in larger libraries, and these sunlit spaces can provide social and way-finding benefits. Also the reduction of the surface area to internal volume ratio can...
deliver further energy savings (and hence carbon emissions). However, the different nature of libraries can limit the opportunity for sustainable design. The book stack area is normally deep in plan and lit by electric lights, and rare book and map collections require specific conditions for their conservation. But within these constraints, efficiencies can be achieved by, for instance, reducing background light levels and employing task lighting at desks (P. Fisher, personal communication, May 17, 2010).

It may be possible to zone larger libraries into areas that can be naturally ventilated, those that need to utilize mechanical ventilation and air-conditioning, and those areas which could operate on mixed mode cycles. The latter employing nighttime cooling would be suitable in parts of the library where strict air-quality requirements are not needed, such as staff
rooms and in the general book stack collections. However, in the IT areas the standards normally prohibit natural light and ventilation. Security of stock and equipment also poses a limit to the degree of permeability of the building’s fabric. However, it is increasingly common to find stack areas that are enclosed to provide the security and ideal environmental conditions mixed with airy reading and study spaces. This dialogue between mass and light mirrors in some ways the patterns implicit in the use of book and digital media. Zoning so that different conditions exist in different parts of the library is a trend encouraged by sustainability.

Since daylighting is critical to energy conservation, roof glazing is often employed to allow daylight to enter from above. Deeply planned public and academic libraries are increasingly designed with large roof lights and stepped cross sections. This allows light to enter the large reading spaces, which are often located on the top floor. Often sun tubes and ventilating chimneys are used, resulting in libraries that have much more active roofs than in the past. The architectural animation of library roofs in the interest of energy efficiency mirrors that of the building facades with their solar shading and dynamic climate screens. A good example is Brighton Public Library, designed by Bennetts Associates, in a large coastal town in southern England. The library, which was short-listed for the Stirling Prize in 2005, has large ventilating chimneys over the main reading room, which takes advantage of the coastal breezes (fig. 5). In turn these refer to the shipping tradition in the English Channel, creating a fusion of environmental and cultural sustainability (N. Chambers, personal communication, May 17, 2010).

Cross ventilation can rarely keep a large library cool in the summer months. Over a typical year more energy is used in cooling the building than heating it. Hence the emphasis is normally upon achieving good winter conditions without loss of energy through ventilation. Typically a library needs four air changes an hour for healthy conditions, and to achieve this without heat loss, most large libraries use a heat-recovery system of ventilation tied to passive solar heating and high thermal capacity of the fabric (Latham & Swenorton, 2007, p. 98). However, the question of heating is closely tied to that of lighting in terms of the energy balance. Ideally, the library will have high levels of glazing on all facades in order to maximize interior daylight levels (usually a minimum of 60 percent facade glazing). This, however, leads to problems such as downdrafts near windows, solar heat gain, and glare. So one consequence is the dependence upon solar shading, interior blinds, and perimeter heating in order to provide good comfort levels in the reading or study spaces at the library edge. Another is the prioritizing of reading areas on north-facing facades. As a result of these forces, key decisions regarding architectural design are driven by environmental factors (S. Mikkelsen, personal communication, June 8, 2010). There is increasing use of mixed-mode methods
of heating and ventilation whereby natural and mechanical systems are hybridized in order to get the right balance between summer and winter conditions, and between reading rooms and stack areas. This is evident at the Humanities Archive Library at the University of Copenhagen, designed by Dissing and Weitling, the modern offshoot of Arne Jacobsen’s architectural office.

Indoor Air Quality
Related to energy consumption is the question of air quality and internal ambiance. A healthy library environment is obviously needed by all, but sometimes the interests of energy efficiency and book conservation can undermine the internal quality of light and air. People tend to like daylight and natural ventilation, so every effort should be made to maximize their presence in the library (http://www.librisdesign.org; Sands, 2008, p. 4). Air quality is affected also by the materials used for finishes, especially their surface treatment. Natural materials provide healthier working environments than those where a great deal of paint, lacquer, and artificial fibers are employed. Man-made synthetic materials such as carpets and floor tiles should also be avoided.

Indoor air quality is also related to external conditions. The choice of site, orientation, and position of the building can greatly influence internal conditions (Baker, 2009, p. 54). The relationship between the internal and external environments should be considered at the briefing stage so that the working conditions for library staff and users are considered early in design preparation.

One of the conflicts often found in libraries is that of attaining ideal conditions for paper media (books and journals), for electronic media (computer screens), and people. Sunlight is a problem that has to be addressed—it fades books and their bindings, it makes screen reading difficult, it raises interior temperatures, it causes glare and visual discomfort. However, daylight is rarely a problem except for special collections and other archival material. So one crucial aspect of energy design is the control of sunlight without eliminating the benefits of daylight. Different
libraries have solved this problem in different ways. Many use external sails or blinds to filter out sunlight (Phoenix Public Library, designed by Will Bruder); others use internal blinds; others too use translucent glazing (Des Moines Library, designed by David Chipperfield), which provides even levels of daylight (often incorporating thermal insulation) but without the problems associated with sunlight. Orientation is critical since it opens up opportunities to exploit natural conditions for the benefit of internal functions.

Air quality is measured in terms of pollution and comfort. Ventilation rates need to be high to maintain healthy and stimulating interior conditions, but visual comfort is equally important, particularly in library settings. In striking a balance between lighting and ventilation, architects are mindful, too, of the needs of different types of users who may possess quite different perceptions of comfort and possibly also sharpness of eyesight. Hence, another trend in recent libraries (particularly in the United States) is the variability in the interior spaces, which are designed to appeal to a wide diversity of users. A good example is Oak Park Public Library in Chicago, with its sunlit top floor reading room and more subdued veterans’ library in the wings (fig. 6).

Public Transport, Social Sustainability, and the Importance of Central Sites

The site chosen for the library has a significant impact upon the amount of energy consumed by those using the building. Since about 25 percent of global energy use is related to transport, decisions affecting the location of the library are important. First, the building should be well served by public transport and this needs to be available during the opening hours of the library. Hence libraries should be centrally located, preferably adjacent to bus, tram, and railway stops. Where they are not, the routes from the bus or train stop to the library should be safe, visible, and legible. Ideally, too, interior public spaces should link through to exterior traffic-free ones as at Vancouver Public Library (designed by Moshe Safdie), thereby signaling their social role.

Since many people choose to walk to the library, their needs should take priority over those on wheels, as at the Idea Store in London’s Whitechapel (fig. 7). Too often pedestrians have the spaces left over after everybody else has taken a slice of the urban landscape. Their routes are often obstructed by barriers, used only with the help of traffic lights or urban tunnels, and are sometimes poorly lit and dangerous. People will only choose to walk to libraries if the routes are designed for pedestrians—attractive and tree lined with seats every few yards. Many elderly people carrying their books are not able to sustain a lengthy journey on foot without periodic rests. Too rarely is the pedestrian put first.

The cyclist also needs to be accommodated. Again cycle routes to the library are required, and safe and secure storage of bicycles is needed but rarely provided. Cyclists also need showers and changing rooms on
arrival. The needs of car users, whether staff or readers, generally absorb what investment is needed in access provision. The ability of the library to integrate with green travel plans is dependent upon fresh thinking by both building clients and their designers. In Denmark the public library has had a more privileged position regarding the wider web of social and transport services. Here the library is (or was until recently) an emblem of infrastructure centrality and social provision.

Water Conservation

Libraries have the ability to capture their own rainwater for use in flushing toilets or irrigating landscape areas. The large flat roofs of typical library buildings provide an opportunity to direct the water into roof tanks where it can then be fed by gravity to the various toilets in the building. The roof needs to be active in terms of water catchment, energy catchment, and biodiversity. With climate change water is becoming an issue in many regions of the world, yet libraries rarely incorporate features in their design to conserve stocks. As a result potable water is used for the relatively low-grade tasks listed earlier and is ignored at the expense of energy conservation.

Water can also be conserved by employing spray taps, self-closing taps, and low-flush toilets. Here the benefits are threefold. First, the cost of
utilities is reduced (thereby saving money for use on other library services). Second, water can be conserved for other more essential purposes such as drinking, cooking, and agricultural irrigation. Third, the use of water-conserving apparatus can help educate the public into practices they should be using in the home or workplace.

**Biodiversity**

The choices architects make in the selection of construction materials and finishes have a large impact upon local and international biodiversity. By bulk around 60 percent of global raw materials end up in the construction industry. The impacts are on rainforests (for structural timber and veneers); mountain ranges (crushed aggregates and building stones); natural river bed deposits (sand and clay); remote regions (ores for steel,
copper, lead); and farmed animals (sheep wool for carpets, etc.). Libraries are long-lived buildings where the initial impacts can serve society well over generations as long as the initial choices are intelligently made. Generally it is better to choose materials with a low ecological footprint. This can be achieved by using locally sourced products where the supply chain is easier to monitor and impacts are nearby rather than further afield. Secondly, by using recycled materials or construction products that lend themselves to reuse (in whole or part), the ecological damage can be reduced.

Biodiversity can also be addressed at the level of landscape design. The linking of the library into the local landscape through the use of green (planted) roofs, the provision of ecological richness through the choice and extent of ground planting, and the creation of sheltered and safe areas for people and wildlife alike can all benefit biodiversity. Also the reduction of waste, both during the construction phase and once the building is in use, can also limit the environmental footprint of the library.

**Noise and Acoustic Zoning of the Library**

Old libraries were silent places; new ones ring to the sounds of chatter, opening program melodies, mobile phone tunes, and keyboard tapping. Nothing signifies the changes libraries have undergone in less than a generation than the attitude to noise. Some libraries make a virtue of background noise, believing that it is an inevitable expression of the life and productivity of the postmodern library. Others cling to the notion of silent areas where the spoken word is prohibited in pursuit of concentration, at least in parts of the building. Noise is an issue that cannot be considered in isolation since strategies for energy efficiency and ventilation impact directly upon the acoustic environment.

The emphasis today is to have a gradation from silent to noisier areas. The role of environmental design is to help, through the distribution and materiality of walls and construction of floors, to reinforce the management’s policy on noise. It is better to establish through good library design the different noise zones than to rely upon signage or the nagging of library staff. Commonly the lower floors permit the use of the spoken word, dialogue around computers, and background noise from cafes. Similarly, the center of libraries are normally noisier than the perimeter where the study desks or reading spaces are located. Between these conditions a number of noise-level bands normally exist in larger libraries with the position of book stacks and location of information desks providing definition of the various acoustic zones.

One problem commonly encountered is that of noise travelling vertically through the library in the atria spaces, which are increasingly employed for energy efficiency. Atria have the benefit of maximizing daylight and cross ventilation in deeply planned libraries. Where single or double
rooms are provided adjacent to atria, the architect must employ secondary walls, screens, or acoustic baffles to prevent the working environment from becoming unusable. As a rule of thumb, research and university libraries are less accepting of background noise than public libraries. However, most public libraries have designated silent areas for individual study, and these are commonly on upper floors where traffic noise is also less intrusive.

In university and college libraries, the growth of group working by students means that certain floors are allocated for this noisier type of activity, especially as it normally entails the use of mixed types of study material. The integration of paper, video, and electronic media occurs also in public libraries, and here there is increasing tolerance of noise by librarians, particularly in inner-city libraries where language barriers have to be overcome. Generally speaking the larger the library, the more acceptable is background noise but, conversely, the bigger the space, the harder it is to design out unacceptable noises.

Seattle Public Library, designed by OMA, cleverly positions bookstacks to act as acoustic screens within the library’s central spiral. Another approach, common in research and university libraries, is to use compact storage as sound barriers between reading rooms. These are sometimes in closed stacks, double story in height, allowing the main reading rooms to be nearly five meters tall (twice the stack height). High ceilings are also beneficial for daylight penetration into deep reading rooms and also for cross ventilation. This is the pattern employed at Bournemouth Public Library, designed by UK practice Building Design Partnership (fig. 8).

The growing use of laptops and the expansion of mobile phones into the realm of education for many younger library users means that the architect must consider noise at the planning strategy stage. The aim is to isolate the areas that generate the most noise (staff rooms, photocopy points, control desks, group study, children’s and teenage library, café areas, or meeting rooms) through space planning. This is necessary in both plan and cross section, since many disruptive noises have the habit of travelling diagonally through the building.

Acoustic disruption also occurs around lifts, escalators, and stairs. Fire protection will normally require these to be enclosed, and this helps with noise control. However, when open stairs are employed, the noise from foot traffic can be considerable unless soft finishes are employed. Using carpeting or cork floors and book stacks, which include acoustic insulation, can help achieve a background noise level of 40 decibels, even in open plan libraries. However, in many city-center libraries, the main noise source is external, and here double or triple glazing may be required.

**Material Considerations**
Most modern library buildings are constructed with concrete or steel frame structures. The use of framing allows light to enter the library
through large areas of glass while also freeing the floors of structural walls, thereby providing flexibility of layout and adaptability for future changes in knowledge media. However, concrete and steel are not attractive materials in their own right and neither are they free of large ecological impact in manufacture. The relative unattractiveness of steel or concrete compared to brick or stone has encouraged designers to employ a wider palette of materials for internal finishes. This includes glass, either on its own or with textured or colored finishes, wood of various types, cork, linoleum, wool carpets, and other natural-fiber fabrics. The aim is to increase the level of comfort and transparency by using materials that introduce into the library (as the architect Dominique Perrault puts it) a “more sensual, sensitive and smooth feeling” (Arets, 2005, p. 172).

The dialogue between structure and finishes is a dynamic one, not unlike that between books and the Internet. Colored or decorative glass is increasingly being employed for interior walls and external skins of contemporary libraries. It has many benefits—aesthetic and environmental—while also creating the ambiance of a social center where, as Rem Koolhaas puts it, “all available technologies to collect, condense, read and manipulate information” can coexist (Arets, 2005, p. 212). In the Seattle Public Library, the glazing system becomes an envelope of unfolding planes that opens up the rich interior of wood veneers and colored walls to exterior gaze. Another common dialogue is between concrete and

Figure 8. Bournemouth Public Library, designed by BDP, uses the architecture of energy efficiency to create a fine civic statement. Photo courtesy of David Barbour/BDP.
timber. Exposed concrete surfaces are used for thermal mass (to stabilize temperatures without using air-conditioning), with timber on walls to help with acoustic absorption. It is a mixture used at Brighton Public Library, where 50 percent of the internal walls are lined in wood in order to reduce noise levels (Evans, 2005, p. 27).

The tactile quality of materials extends to their touch, their visual texture, luster, and to their smell. Materials and finishes add considerably to the sense of comfort and well-being. The books themselves have similar characteristics. To read is to get close to the material of the book, and to do so in surroundings that invite comfort and leisurely reading is to express the deeper nature of being inside a library. Architects can alienate users by excessive employment of hard synthetic materials. The choice of fabrics and finishes made by designers should reinforce library qualities not undermine them.

Environmental Impact of Materials Used in Library Construction

Materials used in library construction have a big environmental impact—in extraction, processing, transport, use, and disposal. This impact exists often at a global, regional, and personal level, affecting climate and biodiversity on the one hand, and the health of people on the other. Resources used in construction account for about a half of all resource consumption in the world. Library architects and engineers cannot claim to be sustainable practitioners without addressing the complex and sometimes contradictory demands of building materials.

Generally speaking there are four main considerations in the selection of building materials or construction products:

- Embodied energy
- Performance over lifetime of building
- Appearance
- Salvage-ability

No single methodology exists to guide those who specify the wide range of construction materials that make up a typical library building. Frequently, the concept of “embodied energy” is employed, but over the life of a building the embodied energy of the materials represents only around 10 percent of the total energy consumed by the building in use. However, the concept of embodied energy does highlight the high-energy transport costs of bulky materials (stone, aggregates, brick, concrete products) and the high-energy processing costs of some commonly used lightweight materials (steel, aluminium, copper). It also informs choices over the selection of renewable energy products such as PV panels, which have particularly high embodied energy coefficients.
There are three important principles that come from an understanding of embodied energy:

- **Source heavyweight materials locally**: Stone, aggregates, bricks, etc., should be specified from quarries or manufacturers located near the construction site. This saves on energy use in transportation and reduces the overall environmental impact (disturbance, noise, pollution). It also helps create local jobs.

- **Source lightweight materials globally**: Most embodied energy relates to transport costs but this is not the case for lighter materials. In the case of aluminium, for instance, the bulk of its embodied energy is the result of the manufacturing process, with a ratio of about five to one in the amount of energy consumed per unit weight. Embodied energy is high in other lightweight materials such as PVC. However, it must be remembered that, once the energy has allowed the manufacture to take place, society has a stock of material resources that can then be used, reused, or recycled.

- **Recycling potential**: Life-cycle assessment (LCA) has highlighted the complex picture of cradle-to-grave environmental impacts. Taking energy as a single issue, the impact of a material depends on initial energy costs (input costs) and the final energy costs (output costs). There is embodied energy at the beginning but also embodied energy at the demolition stage of a library building’s life. Two actions are needed: first, to ensure that the potential for reuse and recycling influences the material choices made at the beginning by designers; second, to ensure that any residual embodied energy is extracted before the material is placed in a landfill site. Residual energy may be extracted via burning, perhaps in a waste incinerator plant, producing electricity, or via composting (where the energy breaks materials down into useful chemicals or by-products).

**Reuse and Recycling**

Recycling is when a material is reprocessed into a new product of the same material type. Aluminium and copper are both commonly recycled, with over two-thirds of all new copper consisting of recycled old copper. The degree of recycling is dependent on world commodity prices—aluminium is currently cheap and abundant, providing a disincentive to recycle. Copper, on the other hand, is relatively expensive and there are measurable limits to the world supply of copper ore. So, whereas only 40 percent of aluminium is currently recycled, 75 percent of copper is. Irrespective of market forces, library architects should select materials on the basis of their recycled content since recycling is less energy demanding than the full process of extraction, processing, and manufacture. The “cradle to cradle” idea of zero waste is having a growing impact on how designers and engineers think.
There are long-term future supplies of sand, stone, and softwoods. Global scarcity does not exist in these areas, and hence they should be selected in preference to metals, plastics, and hardwoods. This will lead to a particular aesthetic and architectural style (a kind of updated vernacular architecture), and when combined with globally sourced high-tech lightweight materials, the combination has the potential to generate energy-efficient, resource-friendly, and responsive libraries. The marriage of local sourcing of commonly available bulky materials and international sourcing of specialized lightweight ones (such as photovoltaic panels or intelligent glazing systems) may well be the basis of library architecture in the twenty-first century. High and low tech will coexist in the same building rather than being hostile neighbors along a street, just as low-tech books coexist with digital media.

**Space Stress and Environmental Issues in Libraries**
The growing popularity of libraries, the relative cheapness of books, and the expansion of IT provision and related social areas, have stressed many existing libraries. Rooms, corridors, stairs, reading areas, stack areas, reference, and archive areas all find themselves used more intensely than in the past. In many ways, the growing popularity of libraries reflects their changing nature from being places to retrieve information to places where people meet and information is generated. In order to accommodate more space for people and their laptops, a greater area of the library is given over to casual seating and workstation provision. Although this supports social sustainability, there are implications for environmental design strategies, especially with regard to ventilation levels and noise transmission.

There is also a trend in all public buildings to which the library is not immune. That is the need to be seen and to observe. Space is for socializing as well as use, and libraries are under pressure to engage in social discourse in much the same way that art galleries attract people irrespective of the collection (fig. 9). Library users commonly meet their friends in the building in order to chat over coffee, to share ideas about books, or to undertake joint Internet searches. In this sense the public library is assuming the fluidity of functions that characterizes the modern hotel lobby (S. Mikkelsen, personal communication, June 8, 2010). The new social uses add to space stress and have consequences for the interior environment.

There are three ways in which these space stresses are commonly resolved: first, to build new flexible libraries that offer greater adaptability than in the past; second, to extend existing library buildings, altering internal configurations and use patterns in the process; third, to reconfigure existing libraries without physical extension. The latter is often employed as a short-term solution to the wider social and technological pressures on today’s libraries. A recent survey of American libraries found that 76
percent of public libraries had their ability to cater for growing IT usage limited by space provision, while 31 percent reported that the existing infrastructure curtailed routes for computer cabling and electrical outlets (American Libraries, 2007, p. 11).

Where internal modification is employed, it usually entails the creation of extra space for IT users at the expense of traditional book users. Here the answer employed, especially in college and university libraries, is to employ compact mobile stacking systems. Effectively, it cuts down on the one-meter-wide space required between each parallel row of book stacks.
With mobile stacking systems, only one corridor of space is needed for up to eight rows of book stack—in effect saving seven meters of library provision to use for other purposes. This can result in compact shelving systems doubling the storage capacity per meter of library compared to traditional library book stacks. However, compact shelving has two main drawbacks: the weight of the compressed stacks can exceed the floor loading capacity, and only one reader can browse the stacks at a time. So with large book collections and lower usage it provides a sensible economy of space (and associated heat and light), but in smaller libraries where there is much demand, it is a false economy in spite of the claims made by manufacturers of such systems.

As a rule of thumb, the book stack area of the public library normally accounts for around 60 percent of the total area, while for a university library it may be as low as 40 percent. Much depends upon whether the stacks are compact or open for use by all readers, whether there is storage elsewhere (say in a basement), and what level of workspace and IT-based provision is to be accommodated. An economy can be achieved in both space and energy use by providing book stack galleries within double height reading rooms—the mezzanine being employed for relatively low stacks, which can be reached without ladders. This is a modification of double-height book stacks of eighteenth- and nineteenth-century libraries, which in turn led to lofty reading rooms. The benefit of mezzanine book galleries is not just functional: the space for reading has the quality of space and light needed for reflection, while the retrieval of books is undertaken in more utilitarian surroundings—perhaps using sensor-based artificial lighting.

Historically, the three main areas of a library have consisted of the general stack area, reference stack area, and reading room. Although we have today many other functional zones (e.g., children’s library, IT suite) the primary three-part division remains true, particularly for larger libraries. However, there is a tension between the major parts, which has been exacerbated by the growth in the number of books and the invasion of CD-ROMs, Internet information systems, and social network sites such as Twitter and Facebook. As a consequence the reading room is often sacrificed or combined with other library and communication functions. The library somehow has to accommodate both traditional and new functions. The ability of the library to encourage intellectual collaboration and knowledge exchange between media and people is an important measure of the social success of a library. Since knowledge is rapidly evolving into new fields and modes, space will inevitably be stressed in the process of delivering the library services of the future.

Although libraries have impressed themselves on public imagination over the last century or more, their design today is changing in unprecedented ways (CABE, 2003, pp. 4–6). It is important in terms of social and
cultural sustainability that the essential identity of the library is not lost (Building Futures, 2004, p. 22). This is particularly true of regions with a strong library tradition such as Scandinavia. Although there are impressive new libraries around the world, most of library investment will be in upgrading existing buildings to serve the challenges of the twenty-first century. Here it is important that the original library spirit is not lost in the pursuit of new media and new library audiences. Sustainability starts with existing buildings not new.

Conclusion
It is evident that libraries, like all buildings, are adjusting to new environmental agendas, especially the imperatives of climate change. However, unlike many buildings, libraries are long-lived and have to survive through different perceptions of environmental and architectural quality. The priority today is energy efficiency, tomorrow it may be energy scarcity—either way clients expect their architects to address sustainability from the start.

Whatever the external demand, there is the overriding need to meet user expectations in terms of the reading or study environment (paper and digital). There are also the needs of library staff to consider. Finally, there are the books, journal, and special collections that need to be protected. The balance of interest has moved over the past century from that of the book and its protection to that of the reader and the reader environment. This socialization of space has had architectural consequences—libraries are now meeting places where ideas are exchanged rather than just absorbed. Space has given over to place, and place is now shaped by genius loci and the search for cultural and environmental identity. The library, particularly the public library, is a carrier of messages: cultural, civic, and environmental.
Looking at library design in the twentieth century, many currents have recurred. The first is that of social idealism linked to good design. Often such design incorporated aspects of what today is called ecological design. Nowhere is this more evident than in the Nordic tradition from Aalto to Jacobsen and more recently in the libraries of Henning Larsen (fig. 10) and Schmidt Hammer Lassen (fig. 11). These have occupied a distinctive place in their communities, beacons of social democracy and of sensitive environmental design. These libraries feature large daylit reading rooms with views out over fields and forests. They are often built of natural materials—mainly wood, stone, and brick—with such materials found inside on floors and walls. Alvar Aalto saw his library at Viipuri in Finland as a clearing in the forest: nature was part of a broad modernist consensus in Scandinavia that embraced the public library (Dahlkild, 2009, p. 70).

Another trend is that of the importance of the public library to local identity and civic pride (Kucharek, 2009, p. 32). Libraries have helped put cities on the map or played their part in wider urban and intellectual regeneration. Nowhere is this more evident than in the United States and Canada where new libraries in Des Moines, Seattle, Chicago, Vancouver, and Montreal have signaled urban rebirth. What makes these libraries interesting as a group is the way they have addressed the environmental and cultural agenda. Climatic design (rather than energy efficiency, which has been the main driver in Europe) has shaped the North American exam-
bles, and in their way they have referred back to building traditions on that continent. Hence, there has been a different kind of continuity than in Europe—a sense that the architecture of cities (rather than nature) matters. So the United States has given us libraries that are monuments to urban and social sustainability, playing their part in “the fundamental landscape of cultural continuity” (Brawne, 1997, p. 27). An example is Des Moines Public Library, which in responding to new environmental forces has rediscovered the midwestern tradition of understatement and aesthetic stoicism (LeCuyer, 2006, p. 62).

This marriage of environmental and cultural agendas has revived the library as a building type. Social change has been fuelled by wider global forces—the need for new information, people migration, global warming—and in turn the library has reinvented itself. The library today is an open building physically and democratically; it carries messages in text, digital media, and architecture. A key trend is that of sustainability, not just in the physical sense, but in terms of social and cultural sustainability. Openness and transparency demanded of energy efficiency allow the library to be a beacon of social and intellectual change as in the design of Oslo Public Library, by Schmidt Hammer Lassen.

REFERENCES