Sustainable Buildings in New Zealand

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1. Summary

There has been significant interest and debate in the concept of sustainable buildings worldwide. One major issue is the definition of a 'sustainable building' and what that actually entails. Most of the focus to date has been on green buildings which may feature energy conservation in construction and operation, recycled or native/natural/low tech materials used in construction or even use of high tech concepts to reduce energy and water consumption. Since so many materials are used in building construction, the issue of sustainability of the building becomes highly complex. This is exacerbated by the short term nature of current aesthetics, architectural design and style which contrasts with the requirement for long term thinking for sustainability. The impact of construction on the environment can be quite high, especially considering the amount of construction which occurs. Moreover, embodied energy has often been used as a measure of sustainability but this fails to take into account other significant impacts from construction. This paper will discuss the concept of sustainable buildings, tools for measuring sustainability and the application of those tools to buildings.

2. Introduction

Much emphasis has been placed on green buildings over the past two decades. The concept began with the environmental movement in the 1960s which started a 'back to nature' concept in the design of houses then moved to energy conserving office buildings in the 1970s. The concept of a green building is, today, so diverse, that it is difficult to define what is meant by the term.

Guy [1] outlines five varying visions of green buildings that are found throughout society – the ecological, smart, comfort, aesthetic and community visions – each with competing discourses (Table 1). While the specific discourses can be argued, each has a differing vision of what constitutes a green building and, consequently, the resulting building not only looks substantially different but functions in a different way.

Today the focus has shifted from green buildings to sustainable buildings. The concept of sustainability has developed considerably since its introduction by the Brundtland Commission in Our Common Future [2]. It is now used by professionals throughout society for many purposes and with many meanings, each delivering a subtly different connotation to the term. Overall, however, there is agreement that inter- and intra-generational equity are important and

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[1] Guy, S., 1997. *Alternative developments: the social construction of green buildings.* Royal Institution of Chartered Surveyors, available at http://www.rics.org.uk/ (May, 2003)

[2] Brundtland Commission, 1987. *Our Common Future.* Oxford University Press, Oxford, UK.

that sustainability of environment, society and economics are also important. The complexity of sustainability is recognised but not yet fully understood.

Table 1. Five competing discourses of green buildings (Guy, 1999)

1. Discourse	Ecological	Smart	Aesthetic	Comfort	Community
Emblematic Issue	sustainability	flexibility	new millennium	sick buildings	democracy
Building Image	polluter	asset	symbol	healthy	home
Risk	planetary survival	market survival	survival	cultural life	individual alienation
Life Cycle	inter-generational	business cycle	design fashion	daily	generational
Rhetoric	ethical	commercial	architectural	medical/ scientific	societal
Design Strategy	reduce footprint	max. efficiency	express nature	living building	create identity
Urban Scale	de-centralised	urbanised	contextualised	contextualised	centralised
Mobility	ban cars	virtual travel	hide car	lessen car-use	minimise trips
Networks	autonomous	integrated	reveal networks	diminish intensity	locally managed
Technology	local, renewable	hi-tech, BMS*	organic, recycled	selective/ nontoxic	appropriate
Evaluation	holistic	cost-benefit	truth to nature	productivity	social cohesion

* BMS - building management system

The concept of sustainability with respect to buildings is still poorly defined. Much of the focus is on the use of energy in buildings. In the UK, approximately 66% of the total energy consumption goes towards buildings and building construction (Vale et al., 1994). In the US, buildings use one third of all the energy and two thirds of the electricity (US EPA, 2003). The energy consumed in operation of the building overshadows that of the construction – 90% is consumed in operation over the lifespan of the building (Winther and Hestnes, [3]). As a consequence, much research has focused on means to reduce energy consumption for house and water heating (Winther and Hestnes, 1999; Eaton and Amato [4]).

The measure of embodied energy or emergy within a building is also used as a major indicator of environmental impact. This measure considers all the energy used in production of building materials and construction of the building, as well as energy needed for disposal or recycling of materials. Since the consumption of energy is also related to the production of greenhouse gases, particulates, acid gases, volatile organic carbons and other air pollutants, this measure also provides an indication of the pollutants released through energy consumption. Embodied energy is often used as the major indicator for sustainability of buildings (Brown and Buranakarn [5] ; Treloar, Owen and Fay, [6]).

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[3] Winther, B.N. and A.G. Hestnes, 1999. Solar versus green: the analysis of a Norwegian row house. *Solar Energy* 66(6): 387–393.

[4] Eaton, K.J. and A. Amato, 1998. A Comparative life cycle assess of steel and concrete framed office buildings. J. Construct. Steel Res. 46(1-3): 286-287.

[5] Brown, M.T. and V. Buranakarn, 2003. Emergy indices and ratios for sustainable material cycles and recycle options *Resources, Conservation and Recycling* 38 (2003) 1 – 22.

[6] Treloar, G J., C. Owen and R. Fay, 2001. Environmental assessment of rammed earth construction systems *Structural Survey* 19(2):99-105.

The use of energy alone has raised concerns that a number of environmental factors are not considered. Urher (1999) points out that the buildings contribute significantly to the environmental burden, quoting Levin [7] for the following contribution levels: use of raw materials (30%), energy (42%), water (25%) and land (12%), and pollution emission such as atmospheric emissions (40%), water effluents (20%), solid waste (25%) and other releases (13%). The impact on the environment results from pollutants, energy consumption, water consumption, land degradation/consumption, resource consumption, waste production and loss of biodiversity incurred throughout the life cycle of buildings, from raw material extraction, processing, construction, building operation and demolition.

Even with consideration of all the energy and other environmental factors, the primary question still arises – what do we mean by a sustainable building? Does focusing on the energy alone ensure that a building will be sustainable? This paper will discuss the concept of sustainable buildings, tools for measuring sustainability and the application of those tools to buildings.

3. Direct consumption of resources

With the overall context of inter-generational equity, there is agreement that risk to the environment (encompassing ecosystems and resources), society and the economy must be minimised over both the short and the long term. To achieve technologies which minimise the risk to the environment requires reductions of a factor between 20 and 50 in resource consumption and efficiency (Jansen and Weaver, 2000).

This will be particularly significant to the construction industry which is a major consumer of resources. Estimates of resource use vary but the US EPA (2003) estimates that a standard wood-frame house uses one acre of forest and produces 3-7 tonnes of waste during construction. Lippiatt [8] states that buildings consume 40% of the gravel, stone and sand, 25% of the timber, 40% of the energy and 16% of the water used globally per year. In the UK alone, it was estimated that about 6 tonnes of building materials is used annually for every member of the population (Cooper and Curwell, [9]).

Much of the waste and consumption occurs during the extraction and processing of the raw material. Mining requires water and energy, consumes land and produces significant quantities of acid and heavy metal contaminated gas, liquid and solid wastes. Timber requires significant tracts of land and amounts of fertiliser and harvesting and processing it requires energy. It is also often grown in plantations which replace old growth forest and significantly reduces biodiversity. Transportation of the material also requires energy and the fossil fuels used for transportation, extraction and harvesting produce greenhouse gases and a range of air pollutants. Processing of metals and minerals often results in major gas emissions; the concrete industry is a major producer of CO_2 while aluminium smelting produces perfluorocarbons, which are very powerful greenhouse gases. Hazardous wastes are often a byproduct, containing heavy metals and, from aluminium smelting, cyanide wastes. Processing of timber includes treatment against rot and pests and usually requires hazardous materials.

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[7] Levin, H. (1997). Systematic evaluation and assessment of building environmental performance (ASEABEP). *Proc. Second International Conference on Buildings and the Environment, CSTB and CI*B, 2, Paris, June, 3–10 *as cited in,* Uher, T.E., 1999. *Absolute indicators of sustainable construction*. Rics Research Foundation, Royal Institution of Chartered Surveyors, available at http://www.rics.org.uk/ (May, 2003)..

[8] Lippiatt, B.C., 1999. Selecting cost-effective green building products: BEES approach. *Journal of Construction Engineering and Management Nov./Dec.1999: 448-455*.

[9] Cooper, I. and Curwell, S. (1997). BEQUEST – Building Environmental Quality Evaluation for Sustainability through Time. *Proc. Second International Conference on Buildings and the Environment, CSTB and CI*B, 2, Paris, June, 515–523.

Recycled materials, while requiring transportation and reprocessing, often consume significantly fewer resources than extraction and processing of raw materials. This is particularly true for metals such as copper, iron and aluminium which can be reprocessed to a quality of that from raw material processing. Both concrete and timber can be recycled or reused but quality of the final product is often reduced. Concrete can be crushed and reused as aggregate for some purposes, particularly paving (Khati and Boyle, 1999) and mortar (Corinaldesi, Giuggiolini and Moriconi, [10]) while good grade timber can be used for making furniture. Since it is difficult to determine whether a used timber beam has stress cracks or other weak points, reusing them as supporting timber is not always suitable. Plastic can be recycled into a number of construction products, including tiles, lumber, heating and wire insulation and carpet.

Huang and Hsu [11] found that over $10x10^6$ tonnes of construction material were extracted for use per year in Taiwan while over $40x10^6$ tonnes of construction waste were disposed of without recycling. The waste included significant amounts of asphalt which had to be imported but could easily have been recycled, thus reducing the material and energy costs of importing $51x10^6$ tonnes of asphalt. Thormark [12] pointed out that 'recycled concrete, clay brick and lightweight concrete can meet the total need for gravel in new houses and in refurbishment.'

Over the lifespan of a building, the materials will have to be maintained and, for some, replaced. Exterior coatings, guttering, piping, walls, and flooring in particular will require repair or replacement on a 5-15 year basis. Effective maintenance can also have a significant impact on reducing requirements for replacement. The decisions here are not made by the builder or designer regardless of the original design; the owner determines what materials are going to be used for repair and how the building is maintained.

The overall investment of resources into a building needs to be considered over the lifespan of the building. Although buildings can easily be designed to last well over 100 years and many traditional buildings are designed for more than 200 years (Morel, Mesbah, Oggero and Walker, [13]), many designers and researchers only plan for 50 years and, in the case of office buildings, even less. Using materials which will be durable and require minimal maintenance reduces the requirement for repairing or replacing the materials or even replacing the building, thus reducing the potential environmental impact. Simply designing and maintaining a building for 400 years rather than 50 will reduce its environmental impact from material resources by up to a factor of 4.

Durability of the building depends on a variety of factors – the design, construction methods, materials, purpose of the buildings, its aesthetics and the owner. The owner is the primary determinant on the lifespan of a building and that may also be affected by current and local fashions in architecture, lifestyles and economics. In addition, new materials which are being developed for exterior cladding, roofing and to replace preserved timber are difficult to assess as their durability and suitability for construction has not been proven over the long term.

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[10] Corinaldesi, V., M. Giuggiolini and G. Moriconi, 2002. Use of rubble from building demolition in mortars, *Waste Management, 22(8): 893-899.*

[11] Huang, S. and W. Hsu, 2003. Materials flow analysis and emergy evaluation of Taipei's urban construction, *Landscape and Urban Planning 63(2): 61-74.*

[12] Thormark, C., 2002. A low energy building in a life cycle—its embodied energy, energy need for operation and recycling potential. *Building and Environment 37(4): 429-435.*

[13] Morel, J.C., A. Mesbah, M.Oggero and P.Walker, 2001. Building houses with local materials: means to drastically reduce the environmental impact of construction. *Building and Environment 36 (2001):1119 –1126.*

Major renovations which change the design of the building will also likely occur. With office buildings, interior layouts are frequently modified to suit the corporate function and about a third of construction activities in Europe involve office refurbishment (Caccavelli and Genre [14]). Although these renovations can be used to improve energy and water consumption and interior air quality as well as refurbishment of worn materials, they are often primarily cosmetic changes to suit the company operations. Such renovations can contribute significantly to the solid waste stream and consume resources.

Regardless, both designers and builders have some influence on building durability. Good design, flexible spaces, quality materials, refraining from fashion statements which could become outmoded, all contribute to the durability of a building. However, the design and construction of many buildings today is undertaken by developers who have little interest in the long term durability of the building and are most concerned with maximising profit over the short term. Unless developers are required to consider long term durability and quality of the buildings they produce, this short term focus will continue to be the driving factor in design and construction of most buildings.

4. Energy

Significant energy is consumed during the extraction, processing and transportation of materials as well as during the construction. Morel et al. (2001) found that use of local materials during construction could reduce energy costs by more than a factor of 3 and could reduce impacts from transportation by more than a factor of 6. The local materials studied by Morel et al. included rammed earth, stone, timber and were compared to use of imported concrete which requires significant energy for processing. Treloar, Owen and Fay (2001) found that rammed earth, using a concrete binder, had an energy load equivalent to that of a brick veneer construction due to the energy required in processing the cement.

Brown and Buranakarn (2003) compared the emergy (total life cycle energy required to provide a service or make a product) of major building materials (Table 2). Aluminium had the highest emergy requirement, with wood lumber being the lowest. By using wood rather than steel beams in a building, the emergy requirement would be reduced by more than a factor of 4, depending on the weight of the lumber and the steel beams.

Table 2. Material extraction and production emergy intensity of building materials (from Brown and Buranakarn, 2003).

Material	**Emergy (solar energy j/ g)**
Wood lumber	0.88
Concrete	1.54
Cement	1.97
Clay brick	2.32
Ceramic tile w/ recycled glass	3.06
Glass	2.16
Steel	4.13
Plastic (PVC)	5.85
Aluminum	12.53

[14] Caccavelli, D. and J. Genre, 2000. Diagnosis of the degradation state of building and cost evaluation of induced refurbishment works, *Energy and Buildings, 31(2): 159-165.*

Since 90% of the energy consumption is over the operational lifespan of the building and energy is the major resource consumed in buildings, achieving significant reductions in energy consumption assist significantly in reducing the resource consumption and improving efficiency. Although a house can be designed to be totally self sufficient for energy and water, much depends on location, climate, availability and potability of local water sources as well as on the attitude of the user. The designer/builder can incorporate some energy saving devices and designs such as solar water heaters, passive heating, composting toilets, etc. which are suitable for local conditions. Again, however, such devices and designs will only be incorporated if a profit can be realised; many developers resist including energy saving measures unless they are required by local councils or are considered essential by buyers in the local community. However, Zydeveld [15] pointed out that up to 80% savings in heating energy and improvements in indoor air quality and thermal comfort could be made in the Netherlands with the inclusion of passive solar design with no additional construction cost and with an additional 10% cost in construction, savings of 90% could be achieved. Four major design principles enabled architects and builders to incorporate passive solar design into their buildings – solar orientation; maximisation of solar gain through low surface loss and high internal volume; high mass within the insulation and avoiding of shading.

The increase in use of materials in a low energy building can, however, mean that there is an increased consumption of materials and energy overall; Thormark [16] found that up to 45% of the total energy use is in embodied energy in a low energy building and that such buildings could have a greater total energy use than that of a building with a higher operating energy consumption. However, 37-42% of the embodied energy could be recovered by recycling of materials.

The building owner and occupants determine which appliances are to be used for the house and the energy efficiency of those appliances as well as how the building will be operated – ambient house temperature, type and number of appliances, conservation measures applied during operation etc. Many of the factors which dictate energy consumption are specific to the occupants and their daily activities: age and composition of occupants (people, pets), amount they are in the building, occupation and monthly income, perception of energy, preference for location within the building etc. (Lucas et al [17]). The use of low energy appliances and conservation measures can reduce energy requirements significantly.

Having considered the energy requirements for material extraction, processing, and recycling and for building operation and maintenance, the sustainability of the energy source needs to be considered. Gagnon, Bélanger and Uchiyama [18] compared the life cycle environmental impacts of renewable, hydro, fossil fuel and nuclear energy sources and found that hydro electricity and wind power were the best sources although the latter required a backup source. Nuclear power was also well rated, primarily as the issue of waste management was not taken into account. Solar and biomass were the next best options with all fossil fuels ranking

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[15] Zydeveld, C., 1998. From simple design principles to 4000 passive solar homes; Factor 4 in energy savings at no cost. *Renewable Energy* 15: 240-242.

[16] Thormark,C., 2001. Conservation of energy and natural resources by recycling building waste. *Resources, Conservation and Recycling 33(2): 113-130.*

[17] Lucas, B., E. Hidalgo, W. Gomez and R. Rosés, 2001. Behavioral factors study of residential users which influence the energy consumption. *Renewable Energy 24 (2001): 521–527.*

[18] Gagnon, L., C. Bélanger and Y. Uchiyama, 2002. Life-cycle assessment of electricity generation options: The status of research in year 2001, *Energy Policy, 30(14): 1267-1278.*

significantly lower due to poor payback, emissions, health effects and future performance. The World Commission on Dams, [19] however, noted that:

> 'Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable…. In too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers and by the natural environment.'

Gagnon, Bélanger and Uchiyama did not take the social concerns into account and minimised the land required by hydro power by considering only the direct impacts. Moreover, there was little comparison of the type of land required; hydro power often affects highly productive areas while solar power can use unproductive desert areas and wind power does not take land out of production.

In considering energy consumption then, the use of existing hydro energy combined with wind power to supply electricity is the most efficient. The major concerns are the use of land, the impact of hydro dams and the limited potential to construct dams for future requirements. As a consequence, rather than focusing on constructing more major dams, efforts should be focused on maintaining existing dams, construction of low impact in-river hydro systems, incorporating alternative sources of renewable energy such as wind and tidal power and improving the performance of solar energy collection.

By including energy generation on site, buildings are then not increasing the load on the existing power supply grid and therefore not requiring that additional generation and plant be constructed. Use of the existing grid primarily as a back up would provide buildings with a reliable power source unless the grid was not well maintained.

5. Indirect impacts of buildings

In addition to the direct life cycle impacts of buildings, there are a number of indirect impacts to the environment and to society. These include infrastructure requirements such as water, electricity, roads and telephone lines, services such as stores, restaurants, schools and hospitals and the changes in land use which result in loss of critical ecosystems and biodiversity and effect watershed integrity. Many of these are considered to be planning issues but the pressure for extended development of land around urban centres by developers often results in economic decisions being made which do not fully consider the indirect impacts of such development.

This is changing as the concept of sustainable urban planning is being accepted more widely by urban councils. However, in New Zealand, such planning is still in its infancy and many developments are being allowed to progress without sufficient planning. The traffic situation in Auckland is a good example of poor consideration of roading requirements for suburban developments.

The indirect costs of any building development are often not measured and are likely to be equal to that of the original building. Cheng [20] found that energy requirements per m^3 of water for water and wastewater plants in Taipei was six times that of the pumping requirements within

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19 The World Commission on Dams, 2000. *Dams and development: A new framework for decision-making.* Earthscan Publications Ltd, London and Sterling, VA November 2000.

20 Cheng, C., 2002. Study of the inter-relationship between water use and energy conservation for a building, *Energy and Buildings 34(3): 261-266.*

a six floor apartment. Hendrickson, and Horvath [21] found that highway, bridge, and other horizontal construction costs were 0.6% of the 1992 U.S. gross domestic product (GDP), industrial facilities and commercial and office buildings were 1.5% of GDP, residential one-unit buildings were 1.9% of GDP and other construction such as towers, water, sewer and irrigation systems, railroads, etc. were 2.4% of GDP. Overall, the direct cost of buildings was 3.4% of GDP while the indirect costs were 3.1%. Although this is not a measure of environmental or social impact, it does provide a relative indication of the material and energy requirements for direct and indirect construction of buildings.

The location of a building or development will also impact on the energy and material requirements over the building lifespan. Transportation requirements for shopping, employment or education, energy requirements for water and wastewater services and loss of energy over power lines are all affected by the distance of the building from services (Hartkopf and Loftness, [22]). The sprawled out character of many urban sites in the US, Canada, Australia and New Zealand result in higher consumption of energy and materials; in addition, the tendency towards longer commuting distances even in Europe is also increasing energy consumption and requiring upgrades in infrastructure services. Hartkopf and Loftness (1999) point out that while cities in the US are expanding outwards, the inner cities are being neglected and losing population while the costs for infrastructure and the loss of arable land are increasing.

Another major factor is the increasing use of land for urban and industrial development. Frequently, the land used is arable, thus removing prime agricultural land from production. Agricultural and grazing requirements are then met through clearing of marginal lands, resulting in loss of ecosystems and biodiversity. Urher (1999) states that urban and coastal development in Australia has resulted in land degradation and erosion, surface and ground water pollution, as well as land clearing required for new developments and the acquisition of more agricultural and grazing land further inland where the rain pattern is irregular and the quality of soil inferior.

The selection of building sites is not usually up to the architect or builder – the decision is that of the local council and the developer or landowner. Yet, when considering the sustainability of buildings, the location must be considered as it obviously has a major impact on the environment. Both architects and builders need to provide input into local planning and decision making if they are to seriously consider building sustainable buildings.

6. Social and cultural aspects of buildings

Within the concept of sustainability, both social and cultural aspects must also be considered. Jackson [23] identified the influence of design of buildings and grounds, neighbourhoods, and towns/regions on aspects of physical and mental health, and social and cultural vibrancy. She emphasised the requirement for 'cross-disciplinary collaboration in urban planning and design, and the participation of residents in shaping their living environment.' Greenery and access to it visually and physically were identified as principal keys to health, elements which must be incorporated into relatively high-density neighbourhood designs. These designs include public

[21] Hendrickson, C. and A. Horvath, 2000. Resource use and environmental emissions of U.S. construction sectors. *Journal of Construction Engineering and Management*, 126(1).
[22] Hartkopf, V. and Vivian Loftness, 1999. Global relevance of total building performance. *Automation in Construction 8 (1999):377–393.*
[23] Jackson, L., 2003. The relationship of urban design to human health and condition, *Landscape and Urban Planning, In Press, Corrected Proof, Available online 24 December 2002*

buildings, open space, mixed land use, and pedestrian walkways to increase physical exercise and enhance civic life. Existing urban infrastructure must contain neighbourhoods to provide larger cultural and business opportunities and reduce reliance on the automobile.

Cultural design is also important and frequently ignored, particularly when architects, developers and builders import concepts into an area. Florides et al. (2001) assessed the consumption of energy by traditional Cyprus houses, imported Western designed houses and insulated houses. They found the traditional house design to be more efficient in its energy use and equivalent to an insulated house in comfort while the imported design performed poorly in the Cyprus climate. Moreover, traditional buildings were often constructed from local materials, giving them an aesthetic harmony with the local environment.

Selah examined the evolution of planning and design in Saudi Arabia and found that with a move towards modernisation there was a loss of how cultural and social aspects were implied in vernacular architectural and urban forms – that architectural and urbanism had been traditionally viewed as more than an agglomeration of buildings and streets (Saleh, [24]). Residents valued features of modern village extensions and landscape elements enhanced the interaction with the physical environment but there were elements of the vernacular villages and landscape that people regretted losing, such as `qasabahs', weekly markets, cultivation of terraces, etc. (Saleh, [25]). He also points out, in an evaluation of the architecture of Arriyadh, that ‘in a city without character, it is almost impossible to talk about value, and any kind of creative or critical manifestation is destined to be absorbed in the void of relativism.’ (Saleh, [26]).

Both the architect and the builder need to recognise the quality of traditional urban and building designs and their function within the local society, culture and living conditions (climate, weather extremes, environmental conditions, local building materials etc.). Some traditional designs use woods which are resistant to local insect infestations rather than more commonly imported softwoods such as pine. The use of such materials should be used to encourage the sustainable management of local resources, including the growth of traditional, local timber, rather than exotic pine plantations. Moreover, urban design needs to consider overall social and cultural function and specific building design should be in harmony with such a function.

7. Sustainability of Buildings

The sustainability of buildings therefore requires more than a simple focus on energy consumption over the lifespan of the building. An integrated urban management system is essential (Table 3), with local councils defining acceptable areas for development such as inner cities and marginal lands; urban population strategies to manage density and overall city population; provision of effective infrastructure for long term management with an emphasis on maintaining existing systems rather than increasing them; requirements for developers to meet urban and architectural design standards, take cultural and social concerns into account and use existing infrastructure capacity in life-cycle building design; facilitate the use, reuse and recycling of local materials rather than imported materials and work with local building material suppliers to provide quality timber to the local market.

[24] Saleh, M., 2001. The Changing Image of Arriyadh City: The Role of Socio-cultural and Religious Traditions in Image Transformation. *Cities 18(5): 315-330.*

[25] Saleh, M., 2001. The decline vs the rise of architectural and urban forms in the vernacular villages of southwest Saudi Arabia. *Building and Environment 36(1): 89-107.*

[26] Saleh, M., 2000. The architectural form and landscape as a harmonic entity in the vernacular settlements of Southwestern Saudi Arabia. *Habitat International 24(4): 455-473.*

Table 3. Estimates of potential reductions and improvements through changes in current building management

Activity	Potential Reduction
Planning	
Increasing urban density	50-90% energy and impacts
Development on marginal lands	40-50% improvement in crop production; reduction of erosion
Integrated urban and architectural design	Improvement in building value
Incorporation of green and open space	Improvement in building value; human health
Human powered transportation	90% energy; improvement in human health
Establishment of mixed growth managed forest to supply industries	50-80% in energy and impacts
Construction	
Passive solar power	50-90% energy
Local source of materials	50 – 80% impacts and energy
Use of low emergy materials	50 – 80% energy
Recycling/reusing materials	40% energy; 10-50% impacts and materials
Water tanks, composting toilets	80-90% external water and energy
Operation	
Low energy, low water appliances	20-50% energy and water
Use of human powered transportation	90% energy; improvement in health
Minimising water and energy use	10-20% energy and water
Maintaining and refurbishing buildings	50-80% over 200 years

Builders, architects and developers need to work with local councils to understand and meet the local needs and limitations of the environment, incorporating passive solar heating, water tanks and composting toilets into designs; reducing or eliminating external water or energy requirements; using local and recycled materials wherever safe and possible and minimising the use of materials with low energy or impact on the environment. Building owners also need to have input into the system and recognise the need for refurbishment and maintenance rather than rebuilding or construction, use of low energy and conservation appliances and measures and accept and value local and recycled materials.

Overall, the system must function within its long term capacities. The land itself should define the limitations of urban sprawl, with priority being given to agricultural land and green space, provision of a vibrant, inner city life and a focus on human powered transportation. The materials that are needed for construction should be primarily derived from wastes from demolished buildings and local, recyclable or renewable materials. Use of water and energy must be limited to locally available sources and infrastructures, without damaging surrounding ecosystems and, if possible, regenerating those which have been negatively affected.

8. Tools to achieve sustainability

The CIB Working Commission (Bourdeau, Huovila, Lanting and Gilham,[27]) identified a number of recommendations towards achieving sustainable construction:

[27] Bourdeau, L., P. Huovila, R. Lanting and A. Gilham, 1998. *Sustainable development and the future of construction*. CIB report publication 25, CIB Working Commission W82, 1998. available at http://bativille.cstb.fr/CIB_Reports_pdf/Synthesis.pdf (May, 2003).

- 'Building owners and clients should have a very important role in disseminating sustainable construction since they represent the demand of the building sector;
- Initiatives which involve planning, industry and constructors through adapted regulations, standards or fiscal measures and incentives;
- Education and training which should be largely used to have sustainable development concepts well known and accepted by all people;
- Developing a common language;
- Designers adopting a more integrated approach to design;
- Manufacturers of building products assessing the life cycle considerations as the basis of product development;
- Building users should see the environmental issues as one aspect of productivity;
- Building maintenance organisations should see environmental consciousness as a factor of competitiveness;
- The development of adapted tools to help in decision making;
- The improvement of the building process itself.'

Many of the tools needed to assist planners, builders and consumers in achieving sustainable buildings are now being developed. GIS systems are proving valuable as planning tools to define, map and manage local regions, including sensitive ecosystems, land uses, soil types, urban densities, watersheds, infrastructure etc. They can also be used to map potential future scenarios, derived from modelling changes to ecosystems, land use, water consumption etc. and thus providing planners with an understanding of the local limitations to growth and, therefore, to planning.

Life cycle assessment is being used to further identify the life cycle impacts of buildings. Peuportier [28] found it to be difficult to use life cycle assessment (LCA) to determine which building materials should be used but LCA was useful in determining the technologies which were suitable. Further research is needed on local levels to identify the best options for materials, technologies, construction methods and designs which are suited to local climates, materials and infrastructure limitations.

New building materials and technologies are being developed but their life cycle impact on the environment is often unclear. Some manufacturers are providing assessments of the LCA of their products, making it easier for builders and consumers to make choices. Overall, the major issue currently is energy, particularly for transportation; research is ongoing to reduce transportation energy requirements and the reliance on fossil fuels.

At this point, few, if any, sustainable buildings have been constructed outside of the developing world. Most buildings require a variety of materials, technologies and appliances that use fossil fuels for extraction, production or transportation. In some cases, local planning rules prevent residents from using rain water for drinking purposes, thus requiring all buildings to use local infrastructure and therefore increasing energy and material requirements. Such rules actively discourage achieving sustainability.

There is a slow movement, however, towards the concept of sustainable buildings, particularly in Europe. Over the next ten years, a greater understanding of local limitations and requirements will enable councils to manage their areas as systems, rather than in the piece-

[28] Peuportier, B., 2001. Life cycle assessment applied to the comparative evaluation of single family houses in the French context. *Energy and Buildings 33 (2001):443-450.*

meal manner usually found in councils today. Hopefully, this will mean that local suppliers will recognise the need for recycling materials and councils will provide support for use of such materials. Local regulations will ensure that the use of water, energy, land and materials is within the capacity of the area. This will enable engineers, architects and others involved with buildings to better make decisions for design and construction of sustainable buildings.

The following checklist is designed to ensure that sustainability aspects are taken into account at the design stage.

9. Sustainable Buildings Checklist

1. Have you considered the embodied energy or emergy for materials proposed for the building is as a major indicator of environmental impact? ☐

2. Are you using life cycle assessment techniques to identify the best options for materials, technologies, construction methods and designs which are suited to local climates, materials and infrastructure limitations? ☐

3. Have you assessed the impact on the environment from pollutants, energy consumption, water consumption, land degradation/consumption, resource consumption, waste production and loss of biodiversity incurred throughout the life cycle of the building, from raw material extraction, processing, construction, building operation and demolition? ☐

4. Have you considered alternative methods of achieving the same result, which will minimised these impacts and be more sustainable? ☐

5. Is it possible to use any recycled materials such as paving, timber or metals? ☐

6. Have you considered the maintenance feasibility and ongoing costs over the lifespan of the building? ☐

7. Have you chosen a suitable design life for the building and assessed durability factors – the design, construction methods, materials, purpose of the buildings, its aesthetics and the owner, over the selected life? ☐

8. Have you considered the degree of self-sufficiency of the building with regard to energy and other services such as water and waste? ☐

9. Have you designed the building to current or anticipated standards for energy efficiency, including any appliances that use energy? ☐

10. Have you considered the indirect impacts to the environment and to society of the building? e.g. infrastructure requirements, local services, land use changes that affect ecosystems, biodiversity and watershed integrity? ☐

11. Have you considered the location and occupant density of the building with regard to sustainable transport options, now and in the future? ☐

12. Can you provide input into local planning and decision making to encourage the serious consideration of sustainable building design? ☐

13. Does the urban design consider overall social and cultural function and is the specific building design in harmony with such a function? ☐

14. Are you using local materials in preference to those imported or transported long distances? ☐