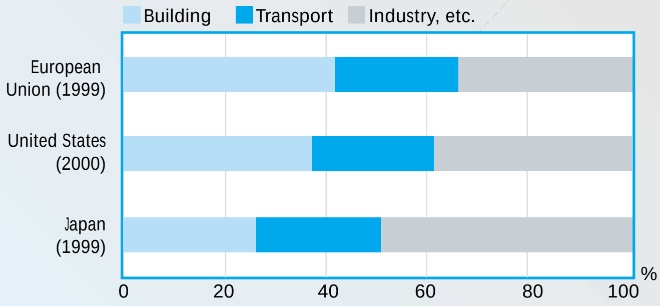
Sustainable building and construction: facts and figures

Industry and Environment first covered the construction industry in an issue published in 1996 with the title "The construction industry and the environment" (Vol. 19, No. 2). A shift in focus over the last seven years is reflected in the title of the current issue, "Sustainable building and construction."

Figure 1
Final energy consumption by sectors



Note: Building sector data represent building operations only; energy use in manufacture and transport of building materials, etc., excluded.

Source: European Commission, US Department of Energy, Japanese Resource and Energy Agency, in *Environmentally Sustainable Buildings: Challenges and Policies*, OECD, 2003.

Sustainable building and construction (SBC) is a holistic, multidisciplinary approach. This approach is increasingly being advocated for buildings and infrastructure. Another way to express this shift is to think of SBC as representing a "sustainable built environment" encompassing the structures and infrastructure we build, the processes used to build them, and the many stakeholders involved (also see the Glossary). Thus "construction" *per se* is only part of the sustainable building process.

Estimates of the amount of time we spend in the built environment – and on it, in vehicles – range from 80 to 90%. Besides the resource and pollution issues surrounding the construction sector, ensuring that the built environment is healthful and pleasant for humans is beginning to be perceived as a crucial productivity issue.

If current patterns do not change, expansion of the built environment will destroy or disturb natural habitats and wildlife on over 70% of the Earth's land surface by 2032, driven mainly by increases in population, economic activity and urbanization.[1]

The world population has more than doubled since 1950. Most of this growth has taken place in the developing world. In the next two decades, around 98% of world population growth will occur in developing countries.[2] By 2007 around half of this mushrooming population will live in urban areas. Three-quarters of the people in developed countries already live in urban settlements. In developing countries the share of the population living in cities is expected to reach 40% before the end of this decade, compared with less than 20% in 1950. Some 60% of the world's fastest growing larger cities (750,000-plus) are in low-income countries.[3] In terms of farmland alone, urbanization claims as much as 40,000 km^2 per year.[4]

These demographic trends translate into increased demand for buildings and infrastructure. The World Bank estimates that by 2015 more than half China's urban residential and commercial building stock will have been constructed during the previous 15 years. World infrastructure needs are estimated at US$ 2 trillion over the next decade and a half or so (Table 1). Developing countries are expected to account for only slightly more of this amount than developed ones.[5]

Table 1
Infrastructure availability and needs

Type of country by income level	% of total world population	Unpaved roads (%)	Population without sanitation (% of urban population)	GDP per capita (US$)
high non-OECD	0.5	15.6	1.1	16,664
high OECD	14.9	18.7	2.4	27,305
upper middle	8.2	44.8	7.5	4,670
lower middle	35.5	52.8	9.5	1,195
low	40.9	71.0	25.4	408

Source: World Bank

The demand for shelter is so pressing in less developed countries that it can only be met by "informal" housing – often self-built, usually illegal, and almost always lacking basic infrastructure. Such housing is estimated to account for 20-30% of urban growth in the largest cities in developing countries. About 54% of the population of Lima, Peru, lives in informal housing.[5]

Impacts of the building and construction sector

Both the existing built environment and the process of adding to it have numerous environmental and social impacts (Table 2). While most available statistics related to these impacts are for developed countries, experts believe on the whole that these impacts are worse in developing than in developed countries. The developing world's share of world construction activities was 10% in 1965, 29% in 1998 and still growing.[6]

Compared with other industrial products, buildings and infrastructure present an unusual case in that they are long-lasting. Structures being built today in developed countries will have an average life of 80 years. In many countries there are buildings, bridges and other structures hundreds of years old. This means the design of, say, an office building or viaduct will have long-term repercussions on a structure's performance and environmental impacts. To end up with a high-performance, low-impact structure, it is vital to incorporate sustainability principles beginning at a project's earliest stages.

Of course, the impacts of buildings and construction are not all negative. Well planned structures built with sustainable methods and materials can be highly beneficial to both communities and workers. The most notable social benefit is the provision of construction jobs, especially for low-skilled and/or entry-level workers.

The overall economic contributions of the construction sector are considerable. Its worldwide market volume amounts to over US$ 3 trillion and accounts for as much as 10% of world GDP, depending on how the sector is defined. Construction is the largest industrial sector in Europe (10-11% of GDP) and in the United States (12%). In the developing world it represents 2-3% of GDP. Construction also accounts for over 50% of national capital investment in most countries. It provides around 7% of world employment (28% of industrial employment) with a workforce of about 111 million, 74% of which is in low-income countries. Developing countries account for 23% of global construction activity – in other words, the construction industry is more labour intensive in poorer countries.

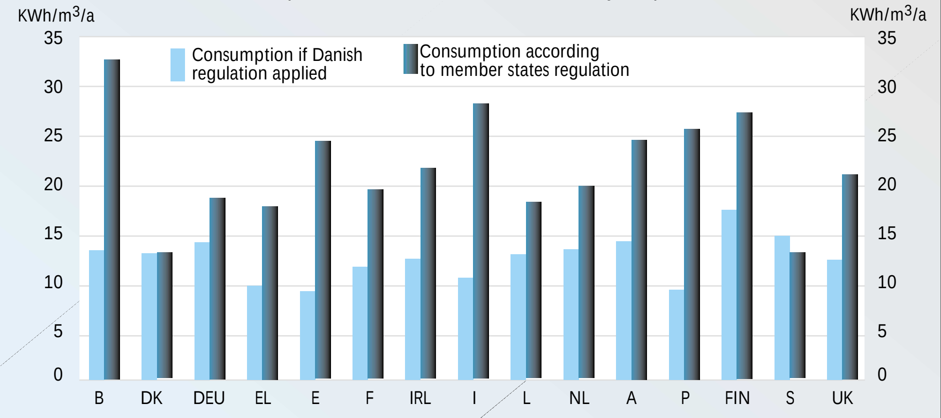
In most countries the building and construction sector is the largest single employer. It is probably the world's largest industrial employer.[8] Its activities involve a very high multiplier effect: the International Council for Research and Innovation in Building and Construction (CIB) estimates that a dollar spent on construction may generate up to three dollars of economic activity in other sectors.

Employment

Potential for growth in the sector's labour force remains considerable in both developing and developed countries. In China the construction workforce tripled between 1980 and 1993, while its share in total employment rose from 2.3% to 5%.[9] In Europe reducing GHG emissions from buildings by 20% would lead to the creation of 300,000 permanent jobs in this sector over a 10-year period (taking into account renovation, retrofitting and maintenance), according to CICA estimates.

One important characteristic of the construction industry is the dominant role of small and medium-sized enterprises (those employing fewer than 250 people, using the EU definition). Some

Figure 2
Projected energy consumption applying model Danish regulation in EU countries (climate corrected; KWh/m^3/year)



Source: European Commission, in *Environmentally Sustainable Buildings: Challenges and Policies*, OECD, 2003.

90% of construction workers worldwide are employed by micro firms consisting of fewer than 10 people.[10] SMEs are also heavily involved in making building materials, especially in developing countries, as well as in associated fields such as architecture and engineering. The EU construction sector includes around 2.5 million construction SMEs representing over 90% of all EU construction enterprises, 16% of all manufacturing, construction and service enterprises, and 80% of construction turnover. Roughly 25% of EU construction workers are self-employed, while about 50% work for micro firms.

In general, the construction industry is overwhelmingly male. However, in South Asia up to 30% of construction workers are women, who perform the least skilled, worst paid jobs.[11] Jobs in construction are often unregistered and hazardous. In the UK, for example, 600 workers die annually from asbestos-related ailments; 40% suffer muscular-skeletal problems and 30% have dermatitis from working with cement. Construction accidents kill at least 55,000 workers a year worldwide, mostly in developing countries.

Job security is a concern, especially in view of the use of casual labour and the growing trend to subcontract. Some 19% of construction workers in the EU are on temporary contracts at any given time (see the article by Alex Wharton and David Payne in this issue). Trade union density, i.e. the percentage of workers who are union members and are not self-employed, is less than 1% in construction in some countries (see the article by Jill Wells). All in all, construction has a poor image. It is seen as providing mainly low-status, low-paid and often hazardous employment.[12]

Environmental effects

Among the direct environmental consequences of construction, the most significant is its consumption of energy and other resources. Construction is believed to consume around half of all the resources humans take from nature (including 25% of the wood harvest, according to a United States Department of Energy estimate). Construction material dominates overall material flows in most countries. Mining and quarrying of materials used in construction generate large amounts of pollution and waste and account for considerable land use. In the case of some metals widely used in construction, such as copper and zinc, shortages are possible by the middle of this century.

In OECD countries, the building and construction sector as broadly defined (including production and transport of building materials) consumes 25-40% of all energy used (as much as 50% in some countries) The International Energy Agency estimates that, on average, one-third of energy end-use in the developed world goes for heating, cooling, lighting, appliances and general services in non-industrial (i.e. residential, commercial and public) buildings.

These estimates do not take into account the "embodied energy" that can be calculated for building products and (with difficulty) for buildings themselves (not all definitions of embodied energy count material transport). This concept, which dates to the 1970s, is essential to the life-cycle approach discussed below. It attempts to calculate how much energy is used in producing a particular item. Transformation of many of the raw materials consumed in construction has particularly high energy demands.

Table 2
Main environmental and social impacts of buildings and construction

◆ raw material extraction and consumption; related resource depletion
◆ land use change, including clearing of existing flora
◆ noise pollution
◆ energy use and associated emissions of greenhouse gases[a]
◆ other indoor and outdoor emissions
◆ aesthetic degradation
◆ water use and wastewater generation
◆ increased transport needs (depending on siting)
◆ various effects of transport of building materials, locally and globally
◆ waste generation
◆ opportunities for corruption
◆ disruption of communities, including through inappropriate design and materials
◆ health risks on worksites and for building occupants

a. Particularly the "Kyoto gases": CO_2, CH_4, N_2O, HFCs, PFCs and SF_6

Since the amount of sustainably produced energy used in buildings and construction (as in most other areas) is relatively small, the bulk of energy use in this sector entails emissions of greenhouse gases. Most notably, cement production is a major source of GHG emissions, both through burning of fossil fuels and breakdown of raw materials. Virtually all the cement industry's output is used in the construction sector, especially for concrete. Twice as much concrete is used worldwide than the total of all other building materials put together.

Based on current trends, CO_2 emissions from the cement industry will quadruple by 2050.[13] Estimates of the industry's contribution of global anthropogenic CO_2 emissions range from 5% to over 7%. The built environment overall is the largest source of GHGs in Europe (in the US, on the other hand, the largest source is transport). The built environment accounts for some 40% of world GHG emissions.[14]

Land use implications of construction are many and varied. Much of the deforestation in developing countries is due to clearing for local building and harvesting of timber for export. Compaction of land by buildings and infrastructure is often irreversible. Land use policies related to land's perceived value for construction frequently result in social inequities, especially where it is in competition with energy biomass production, commercial food crops and other uses.

In terms of reducing transport energy use and demand for land, higher density building is preferable to lower density. However, human living conditions can suffer unless density is compensated for by design. Where land is particularly scarce, the option chosen is increasingly not to build but to renovate. Renovation and maintenance account for one-third of construction activity in Europe (up to 50% in some countries). This share is growing.

Pollution related to buildings and construction is not always obvious. In addition to immediate emissions of air and water pollutants, dust and noise during construction, pollutant concentrations within buildings (stemming from finishes, paints, backing materials and other components) can be over twice as high – in some cases as much as 100 times as high – as concentrations outside. Cement production releases not only CO_2 but also NO_x. Raw material processing and product manufacturing are estimated to be responsible for 20% of dioxin and furan emissions.

The impacts of buildings and construction on water resources are not always straightforwardly quantifiable. They range from discharges to freshwater and coastal waters during mining and raw material processing, to siltation of watercourses from desforestation, on-site spillage during construction and run-off from surface sealing, to freshwater consumption and wastewater generation during building use.

Regarding construction and demolition waste, some OECD countries achieve a reuse and recycling rate of over 80%, though it should be noted that much of the material is used in a low-value-added form, e.g. in road foundations. Overall, this sector accounts for 30-50% of total waste generat-

Model of a business case for SBC

Below are the assumptions used in comparing a standard building project to a green ("high performance") project by Seattle City Light, the electric company of Seattle, Washington, in the United States. It should be noted that the case would not necessarily hold in every type of climate, economic system, etc.

- Each building is mixed use, with 20,000 square feet of retail space and 80,000 square feet of office space.
- Standard building construction cost, excluding land, is US$ 100.36/square foot.
- The green building optimizes daylighting to reduce electric lighting requirements. This also reduces heating, ventilation and air conditioning requirements. Increased cost for daylighting and controls will be offset by reduced HVAC costs.
- A raised floor for air distribution will be used in the green building at an added core and shell cost of US$ 2.00 per square foot.
- Individual office workstation control of ventilation, heat and lighting will be provided at a cost of US$ 1500 per workstation, increasing tenant improvement costs from US$ 10.00 to US$ 14.40 per square foot.
- The resulting construction cost for the green building, excluding land, is US$ 112.58/square foot. (The utility adds that case studies exist showing no increase in construction cost.)

Among the results of choosing the green building:

- Rents are 14% higher than in the standard building.
- Operation and maintenance (O&M) and energy costs are about 30% lower.
- Vacancy and credit losses are down 25%.

In addition, net operating income (NOI) is 27.6% higher (nearly US$ 400,000 a year), while the loan amount reflects the increased construction cost so that net cash flow (NOI minus loan payments) increases by somewhat less than $300,000; still, this is 63.75% more than in the standard project. The increase in NOI raises project value by just over US$ 4 million, or 27.7%.

The rent can be increased because of advantages such as high-benefit lighting techniques, access to natural daylight, superior indoor air quality, the need for lower liability insurance, and fewer worker compensation cases.

Seattle City Light suggests that, depending on project details, the comparative market value may be as much as twice as high, energy costs up to 90% less, O&M costs down as much as 73%, and the overall payback period less than a year.

Seattle City Light case studies (office buildings in US)

Case study 1

- 50% energy savings
- absenteeism dropped 40%
- productivity increased 5%, reducing payback time to under one year (a 100% return on investment)

Case study 2

- 40% reduction in energy
- early estimate of 16% productivity increase with 4-6% increase attributed to individual workstation environmental control
- thermal condition complaints reduced from 40 per day to two per week.

Glossary

No single definition of *sustainable construction* or *sustainable buildings* is accepted worldwide. The European Union defines the former as the use and/or promotion of a) environmentally friendly materials, b) energy efficiency in buildings, and c) management of construction and demolition waste.

The EU definition of *construction* is "on-site production, assembly and disassembly of residential buildings, non-residential buildings and infrastructure by specialist builders." The Confederation of International Contractors' Associations (CICA) defines the *construction industry* as contractors and the *construction sector* as all construction-related activities/professions, including architects, engineers, material producers and facility managers.

Design-build or *design and build* is a system of contracting in which the same company performs both architectural/engineering and construction functions.

Embodied energy is an estimate of the energy needed to make a material or structure available to users. It may include transport of materials. Many practitioners argue that higher embodied energy in materials can be justified if it contributes to lower operating energy.

Facility management is the activity involving "coordination of the physical workplace with the people and work of the organization." It integrates principles of business administration, architecture and the behavioral and engineering sciences. (International Facility Management Association and US Bureau of Labor Statistics)

ed in higher-income countries. That includes waste from renovations, which buildings generally undergo roughly every 20 years in a typical design life of 50 to 100 years.

The controversial question of corruption in the construction sector is both a social issue and an environmental one. In 2000 the anti-corruption NGO, Transparency International, ranked the construction industry as the most willing to pay bribes to government officials in emerging market economies (the arms industry was No. 2). Bribed officials may turn a blind eye to illegal discharges of pollution and waste. Moreover, where corruption involves substandard buildings or building products it can lead to high death tolls in building collapses and natural disasters.

Moving towards solutions

Those in the building and construction sector who are working to make it more sustainable recommend a variety of immediate steps that can be taken to address the environmental impacts of buildings and construction. These include:

- reducing material wastage in construction, including through economic incentives such as higher landfill fees (which also promote the following item);
- increasing use of recycled waste as building materials, not only reuse of construction and demolition waste but also incorporation of other types of waste in building products – as a recent study funded by the California Integrated Waste Management Board confirms, recycled-content building materials generally perform as well as the equivalent standard products;
- improving energy efficiency in buildings (e.g. see Figure 2);
- making wiser use of water in buildings and on construction sites;
- increasing structures' service life, including through built-in flexibility of use.

Longer-term approaches to reducing impacts include:

- rethinking policies affecting the sector, including financial ones, and strengthening standards;
- promoting corporate environmental and social responsibility in the sector, with industry-specific reporting mechanisms;
- building public and enterprise awareness and knowledge sharing;
- upgrading skills and worksite health and safety;
- innovating in regard to materials, technologies and methods, with site-appropriateness in mind and focusing on integrated, holistic research;
- improving data collection and indicator development.

Measures being taken to make buildings and construction more sustainable rely increasingly on life-cycle approaches. Life-cycle thinking in the construction sector takes account of every stage – from a structure's conception to the end of its service life, and from raw material extraction to a building's demolition or dismantling. It also takes account of all actors, from land-use planners and property developers through building owners and users to salvage firms and landfill operators (Table 3).

While Table 3 shows a linear, "cradle-to-grave" life cycle, the material loop can be closed to a great extent through repeated building renovation and material salvage and reuse. A variety of measures and mechanisms exist to promote such moves towards "dematerialization" and other practices that make building and construction more sustainable (Table 4).

Clients and financing

Because designers, architects and contractors cannot always influence design decisions, sustainability criteria need to be integrated into procurement, contracts, tenders and commissioning. However, clients are not always aware of the environmental,

Table 3
Who, what and when in the building process

Stage	Siting/design	Construction/ refurbishment	Use	Demolition/ deconstruction
Actors	Developers Owners Architects and engineers Finance institutions Government authorities	Owners Architects and engineers Contractors Material suppliers Labourers Government authorities Finance institutions	Owners Tenants Building managers Operation and maintenance personnel Government authorities	Contractors Recyclers Salvagers Landfill/incinerator managers Government authorities
Actions and inputs	Choices affecting: land use material use energy and water needs aesthetics transport and mobility	Building materials[a] Chemicals Energy Water Labour Equipment	Chemicals Energy Water Labour	Chemicals Energy Water Labour Equipment
Environment-related impacts and risks	Landscape alteration Transport patterns Building performance (e.g. energy efficiency)	Raw material extraction and transformation impacts[b] Waste Run-off Noise Traffic Landscape impairment Dust Pollutant emissions and discharges	Indoor emissions[c] Waste Wastewater Heat GHGs Soil compaction and contamination Traffic	Waste Noise Dust Release of hazardous materials Soil/water/air pollution (if landfilled/ incinerated)

a) e.g. wood, steel and other metals, cement, stone, aggregate, bricks and other ceramic products, paint and other coatings, glass, plastics
b) e.g. air/water/soil pollution, deforestation, energy use, resource depletion
c) e.g. VOCs, formaldehyde, ammonia, carcinogens, fibres, dust, radiation

Table 4
Policies, measures and tools that promote SBC

Stage of building process	Siting/design	Construction/ refurbishmen	Use	Demolition/ deconstruction
Policies and policy measures	Codes and standards Zoning ordinances Land-use planning Eco-design criteria Procurement policies	Full-cost material pricing Regulations (e.g. energy efficiency) Labour laws and standards On-site EMS[c] Monitoring and reporting	Full-cost pricing Taxes Codes and standards Take-back regulations Disclosure requirements Awareness programmes EMS	Disposal regulations Recycling legislation Taxes (e.g. landfill) Monitoring and reporting
Tools	Life-cycle assessment[a] WLC[b] accounting Sustainability indicators	EPDs[d] ISO 14000[e]	Labels/certification[f] Energy audits Supply chain management	

a) for building or product, e.g. Athena (US DOE), BRI LCA (Japan)
b) whole-life cost
c) environmental management system
d) environmental product declarations, e.g. MVDB (Denmark), MRPI (Netherlands), BVC (Sweden)
e) under development
f) e.g. Blue Eco Angel (Germany), Swan (Norway)

social and economic benefits of sustainable buildings and construction.

Generally, investment in the built environment has long come primarily from:

◆ governments and international financing institutions for infrastructure (e.g. roads, water supply, telecommunications, power supply, sanitation) and public institutions such as schools and hospitals;

◆ private financing for residential buildings (except some social housing), commercial property and related infrastructure.

Increasingly, private financing is playing a role in the first category.

Many forms of public-private partnerships oblige bidders to take operation and maintenance (O&M) costs into account as well as capital costs. One of the oldest such partnership models is "build, own, operate, transfer" (BOOT), in which the contractor must consider operating costs, or even whole-life costs, from the project's earliest stages. Today, however, contracts are generally awarded not on the basis of the shortest period before government ownership, as in the BOOT model, but on the smallest government stake required to make a project economically feasible.

Another type of public-private partnership is the public finance initiative, in which the government makes no capital investment at all (other than fees to have tender documents drawn up, and possibly investment in the land required). Instead it undertakes, in essence, to rent a finished, fully equipped built facility (e.g. school, hospital, prison) operated by a concessionaire.

Thus far, investment in "green" buildings has come largely from the public sector, with sustainable housing supported partly by government funding of demonstration projects (multi-family) and partly by well off individuals (single-family). For all types of clients, education and awareness raising are critical in promoting a trend towards SBC. Corporate image enhancement can be a key motivation in the commissioning of green commercial and industrial buildings.

Notes

1. UNEP/Earthscan (2002) *Global Environmental Outlook 3*. London.
2. WRI/UNEP/WBCSD (2002) *Tomorrow's Markets: Global Trends and Their Implications for Business*. Paris.
3. *Ibid*.
4. Sundquist, B. (2002) The Earth's Carrying Capacity – Some Literature Reviews (www.alltel.net/~bsundquist1).
5. CICA (Confederation of International Contractors' Associations) (2002) *Industry as a Partner for Sustainable Development: Construction*. UNEP, Paris.
6. UNEP/CIB/CSIRCIDB (2002) *Agenda 21 for Sustainable Construction in Developing Countries*. Pretoria.
7. CICA, *op. cit*.
8. *Ibid*.
9. International Labour Office (2001) *The Construction Industry in the 21st Century: Its Image, Employment Prospects and Skill Requirements*. Geneva.
10. *Ibid*.
11. *Ibid*.
12. *Ibid*.
13. A Concrete Foundation. In: *Tomorrow*, 12:6, December 2002.
12. CICA, *op. cit*.
13. OECD (2003) *Environmentally Sustainable Buildings: Challenges and Policies*. Paris.
14. UNEP/CIB/CSIRCIDB, *op. cit*. ◆

Additional resources

There are links to several SBC-related re-sources on UNEP DTIE's International Environmental Technology Centre (IETC) Web site (www.unep.or.jp). Included is information concerning the recently formed SBC Forum (www.unep.or.jp/ietc/sbc/index.asp) and downloadable versions of the Melbourne Principles for Sustainable Cities in English, Spanish and French (e.g. www.unep.or.jp/ietc/focus/melbourneprinciples/english.pdf).

For further information, contact: International Environmental Technology Centre (IETC), 2-110 Ryokuchi Koen, Tsurumi-ku, Osaka 538-0036, Japan, Tel: +81-6-6915-4581, Fax: +81-6-6915-0304, E-mail: ietc@unep.or.jp.

To learn more about the magazine *Sustainable Building*, UNEP DTIE's partner in this issue of *Industry and Environment*, see: www.aeneas.nl/english.

Upcoming events

Modern Earth Building 2003, international conference and exhibition, 24-26 October 2003, Berlin (www.moderner-lehmbau.com/english/programm/index.html)

Global Summit on Performance-Based Building Codes, 3-5 November 2003, Washington, D.C., (www.iccsafe.org/calendar/ircc.html)

2005 World Sustainable Building Conference, September, Tokyo (www.sb05.com) and related 2004 events (www.sb04.org)

CIB 2003 International Conference on Smart and Sustainable Built Environment, 19-21 November 2003, Brisbane, Australia (www.sasbe2003.qut.com)

CIB World Building Congress 2004, 2-7 May 2004,Toronto, Canada (www.cib2004.ca)

Realizing the sector's potential for contributing to sustainable development

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Summary

To support cooperation in the sustainable building and construction sector, consensus-based definitions are needed with regard to what this sector consists of, who the principal stakeholders are and the main issues that need to be addressed. Defining terms helps identify the range of measures that could be adopted, with the overall aim of achieving sustainable development. If the various actors are to take actions that entail non-traditional forms of cooperation, they need to acknowledge that they are part of the same stakeholder community and belong to the same sector, however this sector may be defined. The publications Agenda 21 on Sustainable Construction *and* Agenda 21 on Sustainable Construction in Developing Countries*, together with the EU CRISP project, can function as cornerstones of a conceptual framework and terminology covering every aspect of SBC.*

Résumé

Pour soutenir la coopération en matière de développement durable de l'industrie de la construction, il faut définir de façon consensuelle la composition de cette industrie, quels sont les principaux acteurs et les problèmes à aborder. Le fait de définir les termes aide à déterminer les diverses mesures qui pourraient être adoptées dans le but général de parvenir au développement durable. Si les divers acteurs doivent prendre des mesures qui supposent des formes de coopération non traditionnelles, ils doivent reconnaître qu'ils appartiennent à la même communauté et au même secteur, quelle que soit la façon dont il est défini. Des publications comme Agenda 21 on Sustainable Construction *et* Agenda 21 on Sustainable Construction in Developing Countries*, ainsi que le projet CRISP de l'UE, pourraient servir de fondement à un cadre conceptuel et à une terminologie couvrant tous les aspects du développement durable de l'industrie de la construction.*

Resumen

Para apoyar la cooperación en el sector de las edificaciones y la construcción sostenibles es necesario definir de manera consensual en qué consiste el sector, quiénes son los principales interesados directos y cuáles son las cuestiones fundamentales que hay que abordar. Definir los términos ayuda a identificar las distintas medidas que deben adoptarse con miras al objetivo general de lograr un desarrollo sostenible. Si los distintos actores van a tomar acciones que conllevan formas no tradicionales de cooperación, tienen que aceptar que son parte de una misma comunidad de interesados directos y que pertenecen a un mismo sector, como quiera que se defina este sector. Las publicaciones Programa 21 para la Construcción Sostenible *y* Programa 21 para la Construcción Sostenible en Países en Desarrollo *junto con el proyecto CRISP de la Unión Europea pueden hacer las veces de piedra angular de un marco conceptual y de terminología que cubra todos los aspectos del sector de la construcción sostenible.*

Probably no sector has more potential to contribute to the achievement of sustainable development than building and construction. But this sector is very broad and its organization is fragmented. The application of measures directed towards achieving sustainable building and construction (SBC) requires close cooperation among various professionals, decision makers and other stakeholders.

The many international organizations in the sector have important roles to play in accomplishing such non-traditional cooperation, in communicating how potentially important the sector is to sustainable development, and in attracting the kind of resources that thus far have more often been made available to politically more "sexy" sectors.

In support of this sector-wide cooperation, consensus-based definitions are needed regarding what the building and construction sector comprises, who the stakeholders are, and the main issues involved.

Sectoral contributions to sustainable development

It is important to first define the sector's possible contributions to progress in sustainable development. They can be broken down into various types of measures, each involving different types of organizations and different stakeholders.

For instance, in the area of *sustainable construction per se* – that is, the sustainable production, maintenance and demolition of buildings and of infrastructure such as roads – related measures might include the use of:

- ◆ local materials that do not require long-distance, energy-consuming transport;
- ◆ technologies that generate less construction waste and require less energy;
- ◆ methods of demolition (or preferably deconstruction) that result in more reuse of materials.

Regarding *sustainable buildings and built environment* (buildings and infrastructure that help achieve, or are components of, sustainable development), examples of relevant measures are the design of healthful, less energy-consuming buildings and urban planning that discourages the use of private motorized transport.

In addition, as in any sector, the use of local rather than imported contractors contributes to local and national socio-economic development, and responsible behaviour by employers improves social sustainability. However, this article will focus on measures specific to the buildings and construction field.

Definitions

Research and technology development (RTD) programmes related to sustainable building and construction, especially in developed countries, tend to emphasize the areas of:

- ◆ *energy*, with RTD aiming to reduce energy consumption and promote use of renewable energy sources, such as wind and solar energy;
- ◆ *waste*, including waste prevention through design for reuse as well as recycling of construction materials and waste management;
- ◆ measurement and prevention of the *negative environmental impacts* of construction.

These are indeed important, but SBC can potentially mean much more. Proper definition of terms will help describe the full scope of potential measures geared towards achieving sustainable development.

To many people, the building and construction sector or industry – there is not even a single term acknowledged worldwide – essentially means construction firms, general contractors, and perhaps specialized subcontractors. A broader definition, as implicitly used by some, includes manufacturers of construction materials, components and equipment, and perhaps engineering and design firms.

But to be able to identify a maximum of potential measures to achieve SBC, along with the relevant international organizations and other stakeholders to be incorporated into the debate, it would be best to have a clear understanding of what we are talking about.

Thus, for the purposes of this article, the building and construction sector is defined as all the professionals, firms and organizations (and their representative associations) contributing to the development, maintenance, management and demolition/deconstruction of buildings and other construction making up the built environment.

Figure 1
Components of the building and construction sector

		Phases of the building and construction process				
		Programming and planning	Design and engineering	Construction	Maintenance, management	Demolition, deconstruction
Levels of building and construction	Construction materials, components and technologies					
	(Whole) buildings and the immediate built environment					
	(The wider) built environment (including urban issues)					

Figure 1 shows the various components of this broad definition in the form of a matrix. It is composed of three levels of buildings/construction and five phases in the buildings/construction process, as traditionally organized. In each cell of this matrix different professionals are at work, different stakeholders are involved, and different decision-making processes are crucial. The matrix illustrates both the complexity and the wide scope of the building and construction sector, which must be addressed when defining the stakeholders and potential measures to achieve SBC.

Why is it important to have such a wide-ranging and complex definition, one that in fact differs from other authoritative definitions, e.g. those given in the ISO, CEN (the European Committee for Standardization) and ASTM international technical standards?

Many of the known, potentially important measures, if they are to be successfully applied, require cooperation by professionals, stakeholders and decision makers who are traditionally operating in different cells of the matrix and often do not feel that they are part of the same sector or industry. For example:

◆ An architect – an actor in the cell "Design and engineering" x "(Whole) buildings and the immediate built environment" – designs a housing project with a specific kind of south-facing façade, for reasons related to a desire to reduce energy use. But the city plan, drawn up by an urban planner – an actor in the cell "Programming and planning" x "(The wider) built environment" – does not allow for this. It will take close cooperation between these two professionals and the related decision makers, who work for agencies traditionally unrelated to the sector, to successfully address this dilemma.

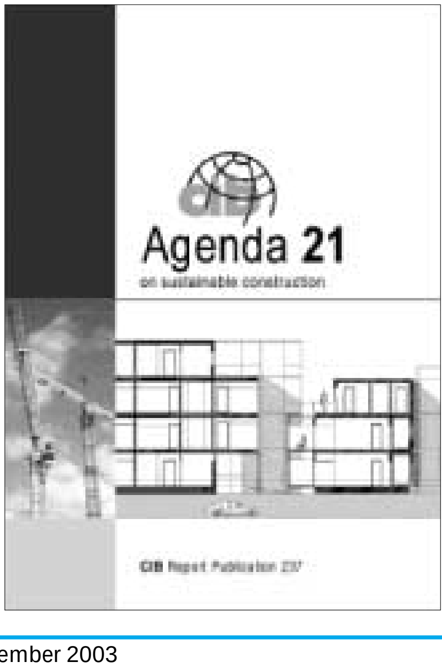
◆ A facility manager – an actor in the cell "Maintenance and management" x "(Whole) buildings and the immediate built environment" – wants to introduce a method to control heating per room in a building, but construction of the building does not allow for this because of the technology chosen by the contractor – an actor in the cell "Construction" x "(Whole) buildings and the immediate built environment".

◆ A building owner – an actor in the cell "Maintenance and management" x "(Whole) buildings and the immediate built environment" – wants to encourage those who work in the building to commute by public transport, but the responsible city planner – an actor in the cell "Programming and planning" x "(The wider) built environment") – turns down a request to adjust the zoning regulations to allow for a bus stop near the building.

Each of these everyday examples contains a measure that could help make building and construction more sustainable. This underlines the need for different actors to cooperate.

For the various actors to be successful in taking measures that may require non-traditional cooperation, they must realize that they are part of the same stakeholder community and that they all belong to the same sector, however wide-ranging and complex its definition.

This is not to say that programmes involving only a single cell in the matrix are in vain. They may motivate or enable people to apply simple measures (and there are many of those) that do not require non-traditional cooperation. Yet all the known "big" measures, from which substantial breakthrough may be expected, do require such cooperation. Thus "the sector" must really act like one, with sector-wide cooperation.



Stakeholders

The next step is to determine which of the many stakeholders have decisive roles in applying more complex and far-reaching measures to building and construction, and who should be primarily targeted by awareness-raising and capacity-building campaigns.

To make it somewhat easier to answer this question, let's assume that properly motivated, educated and facilitated professionals are available in all situations to carry out proper planning, design, construction, management/maintenance and deconstruction. This is oversimplifying things; in many countries, especially developing ones, such professionals may not be available. The assumption also ignores the fact that there is often no consensus-based professional opinion on how appropriate certain tools and technologies are for sustainable building and construction: examples are the various methods of assessing the environmental impacts of buildings, and methods of defining and measuring sustainability performance indicators.

If we nevertheless assume that the required knowledge, tools and technologies are available, as are the professionals to apply them, which key decision makers will ensure that these professionals do a proper job? Who is actually in the driver's seat?

The answer will vary according to market segment and country. The key decision makers on, say, subsidized housing in the Netherlands will differ from those dealing with commercial buildings in Japan or infrastructure projects in Chile. Generally speaking, however, the decisive decision makers when it comes to incorporating sustainability measures in building and construction projects are often:

◆ local governments, including local politicians and agencies;

◆ project developers, the individuals or firms that commission buildings and other projects on a commercial basis to be sold or handed over to owners (note, though, that in many countries, especially developing ones, commercial developers do not exist – at least not yet);

◆ owners of buildings and other construction works in countries where the building and construction market allows them to influence major planning and design decisions, directly or indirectly. Examples are housing cooperatives, government building agencies (which in some countries are expected to set an example) and firms, which sometimes own a very large number of buildings;

◆ national and local regulatory agencies, given that the above decision makers usually have to work within the framework of national (and often also local) regulatory systems, including codes and standards for building and construction, and perhaps even including references to energy performance ratings, environmental impact assessments and other rating and labeling systems.

Unfortunately, these four often decisive actors are usually poorly represented in international debates on sustainable building and construction, while most of the various sector professionals – urban planners, architects, engineers, contractors, suppliers, manufacturers – are generally represented by well organized international associations that do take active roles in such debates. Yet the latter often complain that their members are ready and able to contribute to sustainability in the sector, but are seldom asked to or allowed to by the decision makers. Meanwhile the RTD community keeps developing concepts, methods and tools and analyzing why they do not have the envisioned impact.

With some exceptions, these three groups (actual decision makers, building and construction professionals, and researchers) seldom show much willingness to cooperate towards a common goal of making building and construction sustainable. Their strategic agendas are not often aligned, and their international organizations are not equally represented in international debates. In fact, many of the international debates on sustainable building and construction, while aiming for international strategic or action-oriented agendas, often involve only research topics or, at best, just a few types of professionals.

Joint framework and terminology

On the few occasions when representatives of decision makers, professionals and researchers do have joint debates on SBC, they often seem to be speaking different languages, based upon differing understandings of what SBC entails, differing cultural and educational backgrounds, and differing roles and interests – along with differing definitions of "the" issues, priorities and possible solutions.

A conceptual framework is needed, one that covers all aspects of SBC and incorporates clear terminology that can be understood and used by all parties concerned.

Three existing publications or projects could be cornerstones of such a framework and terminology. All aim to cover every aspect of SBC, in its broadest sense, in an integrated and internally consistent system: *Agenda 21 on Sustainable Construction; Agenda 21 on Sustainable Construction in Developing Countries*; and the European CRISP projects on SBC performance indicators.

Agenda 21 on Sustainable Construction

This publication was produced in English in 2000 by the International Council for Research and Innovation in Building and Construction (CIB) in cooperation with RILEM, CERF, the International Energy Agency (IEA) and the International Society for Indoor Air Quality and Climate (ISIAQ). It was intended to relate the general, non-sector oriented statements on sustainable development in the original Agenda 21 (from the 1992 Rio Earth Summit) to the more specific SBC agendas needed for research and action per country, per stakeholder and/or per aspect of SBC. In the process, it aims to provide the kind of framework and terminology that (if used) would make national, stakeholder-oriented and aspect-oriented agendas compatible.

Agenda 21 on Sustainable Construction distinguishes among the social, economic and environmental aspects of sustainable development for three levels of SBC:

- materials and components;
- buildings and the micro built environment;
- urban environments.

It indicates possible objectives, barriers, challenges and actions for further movement towards SBC in the areas of:

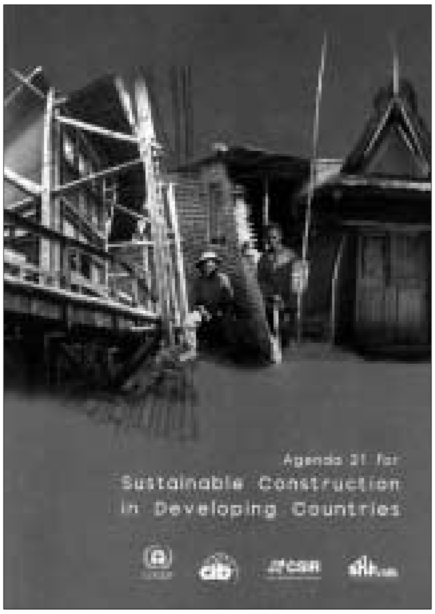
- products and buildings;
- resource consumption;
- process and management;
- urban development;
- social, cultural and economic issues.

This publication has been translated into Spanish, Portuguese, Czech and Catalan. A Russian version is in the works. The English and Czech versions can be downloaded from, respectively, www.cibworld.nl/pages/begin/AG21.html and www. cibworld.nl/pages/begin/CzechA21.html. For the other versions, contact the CIB Secretariat at secretariat@cibworld.nl.

Agenda 21 on Sustainable Construction in Developing Countries

Agenda 21 on Sustainable Construction was strongly dominated by thinking about what could or should be accomplished in developed countries. Barriers and challenges regarding SBC in developing countries are substantially different because of social, economic and institutional characteristics – so much so that some of the suggested approaches may not be feasible for developing countries.

Consequently, a project was begun to produce a special agenda for developing countries. *Agenda 21 on Sustainable Construction in Developing Countries* was published in 2002 by the South African research agency CSIR Building and Construction Technology (known as Boutek) with funding by CIB, UNEP-DTIE-IETC, Boutek and the South African Construction Industry Development Board. It can be downloaded at www.csir.co.za/akani/2002/nov/01.html.



This agenda is not so much a conceptual framework, but rather is more action-oriented than *Agenda 21 on Sustainable Construction*. It focuses on short, medium and long-term actions to develop technological, institutional and cultural enablers for SBC in developing countries.

The CRISP project

The European Thematic Network on Construction and City Related Sustainability Indicators (known as CRISP) is funded by the European Commission. Led by the Centre Scientifique et Technique du Bâtiment (CSTB) of France and VTT Building Technology of Finland, it also involves 22 other European organizations. It is working to develop an integrated system of performance indicators and related assessment methods for sustainability in the building and construction sector – as broadly defined.

More information on the project, its current status and expected outcome can be found at http://crisp.cstb.fr. The results, presented at a conference in late June 2003, are expected to be published in October 2003.

It is hoped that use of this publication and the *Agenda 21* books will improve understanding among international and national organizations representing the various decision makers, professionals and other stakeholders as regards application of SBC measures, and that it will help harmonize the agendas for action that are being developed.

Sustainable development and the building and construction sector

The main challenges facing the building and construction sector in achieving SBC may be summed up as follows:

- The sector pays lip service to the social and economic dimensions of SBC, but they are not well understood, let alone appropriately incorporated in decision making related to building and construction projects.
- There is no clear, consensus-based definition of the sector that includes all stakeholders and enables them to feel part of a stakeholder community, with joint responsibility.
- In many international debates local governments, project developers, owners and regulatory agencies are not well represented.
- A common conceptual framework and key terminology are lacking, which impedes efforts to reach a common basis of understanding of the issues to be jointly addressed.

To these issues should be added what is perhaps the biggest challenge in efforts to achieve SBC: lack of resources to address the decisive issues.

For example, among the multitude of events that took place as part of or in conjunction with the World Summit on Sustainable Development

(WSSD) last year in Johannesburg, only one focused on SBC: the launching of the Global Alliance for Building Sustainability (GABS). Among the thousands of WSSD attendees, fewer than 100 demonstrated any interest in building and construction issues.

The situation in general is much the same – especially as regards politicians, but also on the part of the general public, which is directly affected. Few seem to realize, or have a real interest in, the enormous contributions that the building and construction sector could make towards sustainable development. We in the sector are all aware of the magnitude of its social and economic impacts, the scale of employment in the sector, the amount of waste it generates, the energy it consumes, and the long lives of its products. However, somehow we are not able to get the message across to the political figures who establish national and international RTD budgets in support of sustainable development.

The European Commission, for example, may be the single biggest financer of RTD worldwide, and its strategy – for example, in the Sixth Framework Programme – explicitly presents contributions to sustainable development as a key goal. Yet it prefers to focus its considerable resources on more high-tech, mediagenic sectors.

Clearly the building and construction sector has a major communication problem. Policy makers, politicians and other decision makers on resources for sustainable development do not seem to recognize the sector's potential importance and prefer to fund other sectors. For the many international organizations that represent stakeholders in the building and construction sector, this may be the biggest challenge: to join forces, jointly develop a strong message about what the sector is capable of and how it wants to play a substantial role in achieving sustainable development, and convince those who allocate national and international resources that a dollar spent on RTD for sustainable development in building and construction will have a bigger impact than in any other sector.

Developments towards worldwide sector cooperation

Organization of the building and construction sector is very fragmented: all professionals have their own representative organizations, and almost all organizations focus on one specific role in the process (e.g. planning, design, construction, facilities management) and/or on one level of activity (construction materials and components, whole buildings, the built environment). There is little integrated or holistic thinking. This situation is reflected in the scope and objectives of almost all international organizations in the sector. Most, if not all, state that contributing to SBC is among their prime strategic objectives, but each goes about achieving this in its own way, reflecting its own members' interests and almost never in cooperation with other international organizations. The organizations that do incorporate other players' roles and other levels often focus on one aspect of SBC, such as energy consumption or renewable energy for buildings, or waste from construction.

When looking at initiatives directed towards a more integrated, inclusive approach to SBC in, say, the last five years, at the international level five are of potentially major importance.

CIB: International Council for Research and Innovation in Building and Construction

As its name indicates, CIB has a strong focus on research and innovation. However, its members include representatives of all professions and other stakeholders in the sector, and its objective is to stimulate and actively facilitate worldwide exchange and cooperation. CIB's worldwide membership and wide scope are reflected in its projects, covering all aspects of building and construction. It has concentrated on the theme of SBC since 1995, having refocused many of its expert commissions and established new ones, undertaken international cooperative research and conferences, and issued publications such as the *Agenda 21* books mentioned above. It has also launched strategic partnerships on SBC with international organizations such as the IEA, ISIAQ, the International Federation of Surveyors and UNEP DTIE's International Environmental Technology Centre (IETC), which is the focal point for SBC within UNEP. For a summary of CIB activities especially related to SBC, see www.cibworld.nl/pages/begin/Pro2.html.

iiSBE: International Initiative for Sustainable Built Environments

Launched as an organization in 2000, iiSBe has primarily individual experts as members. Their joint objective is to facilitate and promote the adoption of policies, methods and tools to accelerate the movement towards a global sustainable built environment. A key activity is the management of the Green Building Challenge process, whose intent is to develop the theory and practice of environmental performance systems for buildings. Other activities include the establishment of a dedicated RTD database and joint responsibility, with CIB, for a series of international Sustainable Building conferences. More information can be found at http://iisbe.org.

GABS: Global Alliance for Building Sustainability

GABS was launched in 2002 at WSSD as a voluntary alliance of individuals and organizations. Its objective is to raise awareness for sustainable development in four areas: land, property, construction and development. Although at present it functions as a "virtual" organization only, it has been recognized by the United Nations as a "Type 2 partnership." For more information, see www.earth-summit.net.

SBC Forum

UNEP DTIE launched the Sustainable Building and Construction Forum in 2003, with the objective of facilitating dialogue and exchange of information among key stakeholders (and with their constituencies) on issues related to sustainability in building and construction. Members of this platform are international organizations representing professionals, decision makers and other stakeholders working towards SBC. Information on the SBC Forum can be found at www.unep.or.jp/ietc/sbc/index.asp.

SB04/05 Conferences

CIB, iiSBE, and (more recently) UNEP DTIE are responsible for a series of international conferences that have developed into major events on the SBC scene worldwide. They bring together the widest possible range of experts to discuss various aspects of SBC. The next main Sustainable Building Conference is schedule for Tokyo in 2005, with preparatory regional conferences in Eastern Europe, Southern Africa, Latin America and Asia in 2004. These events are expected to be a focal point for many national and international projects.

Those responsible for these organizations and initiatives are beginning to recognize the need to cooperate or at least align their activities as much as possible. At the same time, platforms are being established for the more focused or specialized international organizations that will contribute to SBC. So far, most activities are more or less voluntary and somewhat incidental, or not really commitment based. But they could provide the foundation for a further, possibly decisive step. Many in the field believe the time may be almost right to start addressing the possibility of establishing a worldwide SBC centre in which international organizations overcome traditional differences, learn to speak the same language, define their common goal for SBC, and join forces to present the world with a united sector whose contribution to achieving sustainable development may be bigger than that of any other single sector. ◆

Towards a sustaining architecture for the 21st century: the promise of cradle-to-cradle design

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Summary

Cradle-to-cradle design is an ecologically intelligent approach to architecture and industry that involves materials, buildings and patterns of settlement which are wholly healthful and restorative. Unlike cradle-to-grave systems, cradle-to-cradle design sees human systems as nutrient cycles in which every material can support life. Materials designed as biological nutrients provide nourishment for nature after use; technical nutrients circulate through industrial systems in closed-loop cycles of production, recovery and remanufacture. Following a science-based protocol for selecting safe, healthful ingredients, cradle-to-cradle design maximizes the utility of material assets. Responding to physical, cultural and climactic settings, it creates buildings and community plans that generate a diverse range of economic, social and ecological value in industrialized and developing countries.

Résumé

Les méthodes de conception qui envisagent un produit depuis sa production jusqu'à la valorisation de ses résidus constituent une approche écologiquement intelligente de l'architecture et de l'industrie qui créent des matériaux, des bâtiments et des modèles d'établissement parfaitement sains et stimulants. Contrairement aux méthodes dites « de bout en bout », elles considèrent les systèmes humains comme des cycles de substances nutritives où chaque matériau a un rôle à jouer dans le maintien de la vie. Les matériaux étudiés comme des substances nutritives biologiques servent de nourriture à la nature après usage ; les substances nutritives techniques circulent dans les systèmes industriels selon des cycles de production, de valorisation et de reconditionnement à boucle fermée. Respectant un protocole à fondements scientifiques pour sélectionner des ingrédients présentant une totale innocuité et bons pour la santé, les méthodes de conception qui envisagent le produit depuis sa production jusqu'à la valorisation de ses résidus renforcent le potentiel des ressources en matériaux. Adaptées au contexte physique, culturel et climatique, elles créent des bâtiments et des projets d'intérêt collectif générateurs de valeurs économiques, sociales et écologiques, dans les pays industrialisés comme dans les pays en développement.

Resumen

El diseño "cradle to cradle" (múltiples ciclos de vida) es un planteamiento ecológico inteligente de la arquitectura y la industria que crea materiales, edificios y patrones de asentamiento totalmente sanos y reparadores. Diferente de los sistemas "cradle to grave" (ciclo de vida único), el diseño "cradle to cradle" considera los sistemas humanos como ciclos nutrientes en los que cada material puede sustentar la vida. Los materiales diseñados como nutrientes biológicos proveen alimento para la naturaleza después de ser utilizados. Los nutrientes técnicos circulan en sistemas industriales en ciclos cerrados de producción, recuperación y remanufactura. Siguiendo un protocolo establecido sobre bases científicas para seleccionar ingredientes seguros y sanos, el diseño "cradle to cradle" aprovecha al máximo la utilidad de los valores materiales. De acuerdo al medio físico, cultural o climático, crea edificios y planes comunitarios que generan una amplia gama de valores económicos, sociales y ecológicos tanto en naciones industrializadas como en países en desarrollo.

As the global flow of advanced architectural materials grows with the expanding global economy, and as even traditional dwellings built with local materials begin to put pressure on natural resources in developing countries, environmental policy makers, business leaders and governments worldwide are increasingly embracing energy and material efficiency to mitigate the impacts of architecture.

But perhaps eco-efficiency's moment has past. "Doing more with less" played a valuable role in slowing ecological destruction in the late 20th century, but it is not up to the challenges presented by the kind of growth and global change expected in the 21st.

Certainly, eco-efficient measures such as the European Union's national targets for energy and material efficiency are laudable attempts to sustain human health and economic growth. But using less fuel to heat energy-efficient highrises or sending less building material to landfills does not address the deep flaws of contemporary architecture and industry; it simply limits the negative impact of poor design.

The result, an easing of ecological stress, has been an important step towards a more just and healthful world. But it is yesterday's step. The time has come to adopt a truly hopeful strategy that will solve rather than merely alleviate the problems associated with buildings and construction, a strategy that will transform architecture into a celebration of a human ecological footprint with wholly positive effects.

Yesterday's ecological footprint

To move towards a sustaining, life-supporting human footprint, it is worthwhile to take a close look at the ideas and practices informing sustainable architecture today. The realization that conventional, modern architecture is not sustainable over the long term is not new. Constructing and maintaining new buildings rivals the global economy's entire manufacturing sector in material and energy use. For over a decade UNEP and other international bodies, along with an expanding network of NGOs, have been striving to shift the priorities of governments, businesses and architects towards more environmentally sound practices.

But how effective are the typical approaches to design for sustainability? Most are aimed at using energy and material more efficiently, a strategy that grows from the idea that decoupling material use from economic growth can sustain architecture and industry over the long term. This would seem to be a critical insight. A report by the World Resources Institute projects a 300% rise in energy and material use as world population and economic activity increase over the next 50 years. As long as economic growth implies increased material use, it warns, "there is little hope of limiting the impacts of human activity on the natural environment." But, the report continues, if industry can become more efficient, using less material to provide the goods and services people want, economic growth can be sustained – and thus decoupled from resource extraction and environmental harm.[1]

The same study found, however, that despite 25 years of dematerialization by five of the world's most potent economies, waste and pollution in those nations had increased by as much as 28%. Though many European nations in the past ten years have achieved significant reductions in waste, they are merely reaching for sustainability, which is, after all, only a minimum condition for survival.

It is true that efficiently constructed buildings can cut waste, and that lighter materials can minimize resource consumption. But while designers may make material substitutions – super-efficient glass, triple glazing, recycled plastic – the chemistry of materials in efficient buildings tends to be the same as that in their more gluttonous contemporaries. And that still presents a serious threat to human health.

Materials and human health

Indeed, *none* of the materials used to make contemporary buildings is specifically designed to be healthful for people. Even a cursory inventory begins to suggest some of the challenges facing architects.

Consider the ubiquitous use of polyvinyl chloride. Better known as PVC or vinyl, it is commonly used for windows, doors, siding, flooring, wall coverings, interior surfaces and insulation. Many PVC formulations contain plasticizers and toxic heavy metals such as cadmium and lead. Plasticizers are suspected of disrupting human endocrine systems, cadmium is known to be carcinogenic, and lead is a neurotoxin.

Equally common are the volatile organic compounds, some of which are suspected carcinogens and immune system disruptors, which are released from particleboard, paints, textiles, adhesives and carpets. Design flaws that trap moisture in buildings and add mould to the substances fouling indoor air, as well as the products developed to fight mould, appear to be generating a permanent breeding ground for resistant microorganisms. The widespread presence of wood preservatives and lead rounds out this formidable array of harmful materials.

Energy efficient buildings, which are designed to require less heating and cooling, and thus less air circulation, can make things worse. A recent study in Germany found that air quality inside several highly rated energy efficient buildings in downtown Hamburg was nearly four times worse than on the dirty, car-clogged street.[2] For all the care taken to save energy by keeping out the elements with better insulation and sealed windows, no one considered the long-term effects of sealing *in* the chemically laden carpets, upholsteries, paints and adhesives used to finish the interiors.

The effects are hard to ignore. When buildings with reduced air-exchange rates are common, so are health problems. In Germany, where tax credits support the construction of energy efficient buildings, allergies affect 42% of children aged six to seven, largely due to the poor quality of indoor air.[3]

Eco-efficient buildings also have a cultural impact. Following the old modernist aesthetic, they tend to be steel and glass boxes short on fresh air and natural light, their internal ecosystems divorced from their surroundings. Whether located in Frankfurt or Indonesia, they are the same. Architecture critic James Howard Kunstler has called such structures "intrinsically despotic buildings that [make] people feel placeless, powerless, insignificant, and less than human."[4]

Are these the kind of buildings we want all over the world? Can't we do better?

Cradle-to-cradle design

We can. Cradle-to cradle design raises an entirely different agenda. Rather than seeing materials as a waste management problem, as in the cradle-to-grave system, cradle-to-cradle design is based on the closed-loop nutrient cycles of nature, in which there is no waste. By modelling human designs on these regenerative cycles, cradle-to-cradle design seeks, from the start, to create buildings, communities and systems that generate wholly positive effects on human and environmental health. Not less waste and fewer negative effects, but *more positive* effects. Imagine, for example, buildings that make oxygen, sequester carbon, fix nitrogen, distill water, provide habitat for thousands of species, accrue solar energy as fuel, build soil, create microclimate, change with the seasons, and are beautiful.

One need not simply imagine such places. By clearly understanding the chemistry of natural processes and their interactions with human purpose, architects can create buildings that are delightful, productive and regenerative by design. This represents a radical shift: from inanimate, one-size-fits-all structures into which we plug power and largely toxic materials, to buildings as life-support systems embedded in the material and energy flows of particular places. The presence of such buildings around the world suggests that human activity can indeed create footprints to delight in rather than lament.

This is not just wishful thinking or "concept" design. The cradle-to-cradle philosophy is driving a growing movement devoted to developing safe materials, products, supply chains and manufacturing processes throughout architecture and industry. It is being adopted by some of the world's most influential corporations, including BASF, the world's largest chemical company; Shaw Industries, the world's largest carpet maker; Ford Motor and its major suppliers in the auto industry; and a host of prestigious designers and manufacturers of textiles, furniture and other objects. Even in nations as vast and influential as China, organizations such as the China-US Center for Sustainable Development are adopting this new paradigm to develop healthful buildings, safe industrial processes and sustainable community plans.

Here's why. Cradle-to-cradle design is animated by ecological intelligence. In the natural world – a grand, evolving system based on hundreds of millions of years of research and development – the processes of each organism contribute to the health of the whole. One organism's waste is food for another, and nutrients and energy flow perpetually in closed-loop cycles of growth, decay and rebirth. Waste equals food. Understanding this natural system allows architects and designers to recognize that all materials can be seen as *nutrients* that flow in natural or designed metabolisms.

Nature's nutrient cycles comprise the *biological metabolism*. The *technical metabolism* is designed to mirror the Earth's cradle-to-cradle cycles; it's a closed-loop system in which valuable, high-tech synthetics and mineral resources circulate in an endless cycle of production, recovery and reuse.

By specifying safe, healthful ingredients, designers and architects can create and use materials within cradle-to-cradle cycles. Materials designed as *biological nutrients*, such as textiles for draperies, wall coverings and upholstery, can be designed to biodegrade safely and restore soil after use, generating more positive effects, not fewer negative ones. Materials designed as *technical nutrients*, such as infinitely recyclable textiles, can provide high-quality, high-tech ingredients for generation after generation of synthetic products. And buildings constructed with these nutritious materials, and designed to respond to local energy flows and cultural settings, encourage patterns of human settlement that are restorative and regenerative.

Waste equals food: from dematerialization to rematerialization

Cradle-to-cradle design yields an entirely new relationship to materials, energy and the making of things. Where eco-efficient designs aim to dematerialize – minimizing the negative effects of toxic materials and polluting fuels – cradle-to-cradle design seeks the *rematerialization* of safe, productive materials in systems powered by the sun.

Rematerialization can be understood as both a process and a metaphor. In the industrial world it refers to chemical recycling that adds value to materials, allowing them to be used again and again in high-quality products. As a metaphor growing from this process, it suggests a design strategy aimed at maximizing the positive effects of materials and energy and participating in the Earth's abundant material flows.

Nylon 6 provides a good example of rematerialization. This widely used polymer can be chemically recycled into the raw material caprolactam, which can be used to make generation after generation of high-quality carpet fibre. In effect, the process virtually eliminates waste – very little energy or material is lost. Given the hundreds of millions of pounds of carpet fibre that each year are sent to landfills or incinerators or recycled into products of lesser value, the significance of rematerializing nylon 6 is enormous. And it suggests an effective new model for material flows.

The model is changing real-world business. Shaw Industries, for example, has examined the material chemistry of its carpet fibre and backing to assess the healthfulness of its dyes, pigments, finishes and auxiliaries – everything that goes into carpet tile. Out of this rigorous process has come the promise of a fully optimized technical nutrient. Shaw now guarantees that all its nylon 6 carpet fibre will be taken back and returned to nylon 6 fibre, and its safe polyolefin backing returned to safe polyolefin backing.

Rematerialization makes conventional recycling

The roof of 901 Cherry (offices of Gap, Inc.) recreates the native habitat of grasses and wild flowers. Its form derives from the surrounding landscape. © William McDonough + Partners

look obsolete. Most recycling is actually downcycling, a loss of value over time with materials losing value. When various plastics are recycled into countertops, for example, valuable materials are mixed and can't be recycled again. New ultra-light composite materials are hybrids from the start; they can't even be recycled once. And when metals such as copper, nickel and manganese are blended in recycling, their value is lost forever.

The key to effective rematerialization is defining material chemistry and tracking material flows. A materials passport – a tracking code created with molecular markers, for example – makes that possible. The passport guides materials through industrial cycles, routing them from production through reuse, defining optimum uses and intelligent practices. With a passport, valuable construction materials can be rematerialized into valuable construction materials, not recycled into hybrids of lesser value heading inexorably towards the landfill.

When conceived as nutrients, high-tech materials can be safely and effectively used in every phase of construction. Cradle-to-cradle geopolymers, for example, are a promising replacement for concrete, which leaches harmful chemicals on building sites and in landfills. Made from local earth and high-quality plastic, geopolymers are far more stable than concrete and require far less embodied energy to produce. Design for disassembly allows building materials made of geopolymers to be used again in new buildings. Or they can be returned to technical cycles and used in other high-quality products. Another material designed as a technical nutrient, a polystyrene foam engineered by BASF, is being developed as a structural material for low-cost housing in developing countries.

Safe biological nutrients can be used throughout interiors, generating healthful effects during production and use and even after they wear out. A textile we designed, woven of wool and ramie and processed with completely safe chemicals, provides an attractive, healthful upholstery fabric and can nourish the soil when it wears out. At the Swiss mill where the fabric is produced, the trimmings serve as garden mulch. The water leaving the factory is as clean as the water flowing in.

Rematerialization and cradle-to-cradle design can be applied with high-tech or low-tech methods to new or existing buildings. Harmful materials in existing buildings can be replaced with healthful ones. Old buildings can also be restored with new designs and technologies that harvest the sun's energy – examples include the Audubon Society's century-old headquarters in Manhattan and the venerable Field Museum in Chicago – or flexibly refitted for a variety of new uses.

Intelligent materials pooling

Rematerialization on a large scale can be achieved through a nutrient management system we call intelligent materials pooling. This system, designed to effectively manage flows of polymers, rare minerals and high-tech materials for industry and architecture as well as local, low-tech flows of natural resources, calls for cooperative networks geared to optimizing materials' value.

In an intelligent materials pool, multiple companies share access to a supply of a high-quality material such as nylon 6 or copper. In effect, partners draw materials from the pool to create products and replenish it with materials they have recovered after a defined period of use. Sharing resources and knowledge, information and purchasing power, partners in a materials pool ideally develop a shared commitment to generating a healthy system of material flows and to using the safest, highest-quality technical ingredients in all their products.

From a strategic perspective, the process begins with an agreement by several companies to phase out an environmentally dangerous material such as PVC. Out of this shared commitment comes a community of companies with the market strength to engineer the phase-out and develop innovative alternatives. Together they specify preferred materials, establish defined-use periods for products and services, and create an intelligent materials pool.

Design and the laws of nature

Cradle-to-cradle architectural materials realize their full potential within cradle-to-cradle buildings. The context of material use is always the larger design, and the larger design always unfolds in the overarching context of the natural world.

Cradle-to-cradle building design is thus the process of discovering beneficial, fitting ways for humans to inhabit the landscape. In every landscape, nature is our guide. We study landforms, hydrology, vegetation and climate, trying to understand all the natural systems at play in each place we work. We investigate environmental and cultural history, study local energy flows, and explore the cycles of sunlight, shade and water. Out of these investigations comes an "essay of clues" – a map for developing healthy and creatively interactive relationships between our designs and the natural world.

The sun is the key to the whole show. When sunlight shines upon the Earth, biology flourishes and we celebrate its increase – the growth of trees, plants, food and biodiversity. This is good growth. When human activity supports ecological health, that's good growth, too. In fact, we can create buildings that make the energy of the sun a part of our metabolism, allowing us to tap the effectiveness of natural systems and apply architecture to positive purpose.

At Oberlin College, William McDonough + Partners (WM+P) designed a building like a tree: a building powered by the sun, enmeshed in local nutrient flows and beneficial to the landscape. Built in northern Ohio, the Adam Joseph Lewis Center for Environmental Studies was designed to ultimately generate more energy than it consumes. Solar power is collected with rooftop cells and sunlight pours through southwest-facing windows into a two-story atrium, illuminating the public gathering areas. Wastewater is purified by a constructed marsh-like ecosystem that breaks down and digests organic material and releases clean water. The upholstery fabrics will feed the garden, and the carpets will be retrieved by the manufacturer and reused for new, high-quality carpets.

Lit by the sun, refreshed with fragrant breezes, in tune with its place through local flows of energy and matter, the Oberlin building's ecological footprint strongly confirms that the human presence in the landscape can be positive, restorative and 100% good.

Cradle-to-cradle economics

Cradle-to-cradle design also makes extraordinarily good sense economically and socially. This is especially visible in the workplace. When designs for large-scale factories and offices are modelled on nature's effectiveness, they generate delightful, productive places for people to work. This not only encourages a strong sense of community and cooperation, it also allows efficiency and cost-effectiveness to serve a larger purpose.

Consider the corporate offices for Gap, Inc. in San Bruno, California. Aiming to enhance the qualities of the local landscape, WM+P designed an undulating roof covered in flowers and grasses that mirrors the local terrain, re-establishing several acres of the coastal savannah ecosystem that had been destroyed by human intervention over the past century. The living roof also absorbs storm water and provides thermal insulation, making the landscape an integral part of the building's energy systems.

Other features maximize local energy flows. A raised-floor air system allows evening breezes to flush the building, while concrete slabs beneath the floor store the cool air and release it during the day. The windows are operable and the delivery of fresh air is under individual control. Daylighting provides natural illumination. This is an open design with common spaces.

The building's advanced integrated systems are so effective, it was recognized as one of the most energy efficient buildings in California. By aiming to maximize positive effects, the design outperformed buildings that set efficiency as their highest goal.

The building's high performance is replicable. The Herman Miller furniture factory in Holland, Michigan, like the Gap building, was designed to foster a spirit of community among employees while enhancing the local environment. An effective, celebratory design achieved both – and more. Not only did the building's site plan include extensive constructed wetlands that rebuild soil fabric, provide habitat and purify storm water, but its design, which maximizes fresh air and sunlight, generated increased worker satisfaction and productivity gains of 24%. Corporations locating in developing countries might take note: designing for human and environmental health supports economic productivity.

Cradle-to-cradle planning

The benefits of cradle-to-cradle design are not limited to individual buildings. In Chicago, where Mayor Richard Daley is on a quest to make the city the greenest in America, cradle-to-cradle principles are providing an inspiring reference point for a host of citywide initiatives. Building on years of innovative environmental programmes, the City of Chicago is now developing community plans and cradle-to-cradle systems that will make it an international model for cities seeking designs that allow industry and ecology, human settlements and the natural world to flourish side by side.

Among many other initiatives, Chicago has agreed to buy 20% of its power from renewable sources by 2006, which is spurring the local development of renewable energy technology. Indeed, some renewable energy companies have moved into the city's new Chicago Center for Green Technology, an ecologically-intelligent facility built on a restored industrial site. Looking ahead, we see Chicago becoming a hub of green manufacturing and transit, energy effectiveness, environmental restoration and cradle-to-cradle material flows – all of which adds up to flourishing human communities that generate an abundance of ecological, economic and cultural wealth.

Cradle-to-cradle systems can generate this wide spectrum of wealth worldwide, in industrialized and developing nations alike. In rural China the people of Huangbaiyu, led by local entrepreneur Dai Xiaolong, are developing a Cradle-to-Cradle Village that aspires to be powered by the sun, with all materials maintained in closed-loop technical and biological cycles.

Significantly, the Cradle-to-Cradle Village is not an idea being imposed on Huangbaiyu by the Chinese government or by an international aid agency; it was generated by Mr. Dai's enterprising leadership, which has drawn support from Tong Ji University in Shanghai, the China-US Center for Sustainable Development, and WM+P. Mr. Dai's plan is based on investing in and growing Huangbaiyu's existing capacity to become more economically self-reliant and regenerative. The chairman of the Tianyuan Eco-Cattle Farm, a successful business with subsidiary companies that include a brewery, breeding farm, organic fertilizer factory and trout fishery, Mr. Dai is well versed in nature's cradle-to-cradle systems and is applying them to the Huangbaiyu community development plan.

This plan is centred on the building of a compact settlement which will make maximum use of Huangbaiyu's available agricultural land, generate optimal conditions for closed-loop material flows, and provide services and amenities that cannot be effectively furnished to a dispersed population. Local workers will employ straw bale construction to build the village's 300 homes, taking advantage of an essentially free local material with proven insulating capacity. A community well will provide clean running water, a resource typically in short supply. Human and animal waste will be collected at centralized locations and used to produce biogas, which will in turn be used for heating and cooking. There will be street trees, public parks and a village school. The people of Huangbaiyu will be steadily employed in a variety of local enterprises, from sustainable forestry to farming to working in the biogas faciltity or a wood products plant. The enduring cycles of nature, it is hoped, will generate a wide spectrum of community wealth.

A diversity of sustaining cradle-to-cradle visions could come to fruition in many places. From high-tech Chicago to rural China, from Japanese temples to American factories, the principles and practices of cradle-to-cradle design are already creating hopeful changes in the world. Ultimately, we believe intelligent design can lead to ever more buildings, communities, cities and nations that honour not just human ingenuity but harmony with the exquisite intelligence of nature. When that becomes the hallmark of good design, we will have entered a moment in human history when the things we make will truly be a regenerative force.

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Life-cycle analysis of the built environment

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Summary

Life-cycle thinking is a holistic approach to environmental and social issues. This approach is key to the sustainable construction concept. LCA (life-cycle analysis, or life-cycle assessment) is an important tool for use in applying life-cycle thinking to building and construction. LCA can yield vital information on material and energy flows. Because it is difficult to apply to buildings per se, the focus is increasingly on carrying out a more general analysis of the built environment. Knowledge gained through LCA can best be used as part of an integrated design process. In the case of most projects, a complete LCA is not affordable unless it is integrated with other tools such as quantity surveying or energy simulation. Priorities for the use of LCA applications in policy making will vary according to regions and economic considerations.

Résumé

La démarche fondée sur le cycle de vie envisage les problèmes environnementaux et sociaux comme un tout. C'est la clé même du concept du développement applicable au secteur de la construction. L'analyse du cycle de vie (ou évaluation du cycle de vie) est un outil important qui permet d'appliquer à la construciton cette démarche. Elle peut fournir des informations vitales sur les flux de matériaux et d'énergie. Parce qu'elle est difficile par nature à appliquer aux édifices, la tendance est de plus en plus à une analyse plus générale de l'environnement bâti. Les connaissances acquises grâce à l'analyse ou évaluation du cycle de vie peuvent être utilisées dans le cadre d'un processus de conception intégré. Pour la plupart des projets, l'analyse ou évaluation du cycle de vie n'est pas financièrement envisageable, à moins d'être intégrée à d'autres outils tels que l'étude des quantités ou la simulation énergétique. Dans l'élaboration de la réglementation, les applications de l'analyse ou évaluation du cycle de vie seront dictées en fonction des régions et de considérations économiques.

Resumen

El concepto de ciclo de vida es un enfoque holístico de problemas sociales y medioambientales. Se trata de un enfoque clave para el concepto de la construcción sostenible. El ACV (análisis del ciclo de vida) es una herramienta importante para aplicar criterios de ciclo de vida a los edificios y a la construcción. El análisis de ciclo de vida puede generar información vital sobre los flujos de material y energía. Ya que resulta difícil efectuar este análisis en los edificios por sí mismos, se apunta cada vez más hacia un análisis más general del ambiente construido. Los conocimientos que se obtienen mediante el ACV se pueden utilizar mejor como parte de un proceso de diseño integrado. En la mayoría de los proyectos, no es posible costear un ACV completo a menos que se incluya con otras herramientas como los presupuestos cuantitativos o la simulación energética. Las prioridades para la utilización de aplicaciones ACV en la elaboración de políticas varían según las regiones y las consideraciones económicas.

The built environment is at the origin of most of the mass and energy flows for which man is responsible. It absorbs large economic resources and embodies considerable cultural capital. Its form and composition may vary from place to place, but the built environment invariably constitutes a principal societal resource in the modern world.

Sustainable development of the built environment is concerned with trying to enhance this resource – as an economic asset – while simultaneously achieving many related ecological, social and cultural objectives. However, given the scale of resource flows and corresponding impacts, sustainable development is ultimately about transforming the built environment in ways that will make possible our long-term survival.

Any attempt by North or South to clearly define objectives for sustainable development, or to evaluate progress in meaningful terms, must be rooted in formal methods and tools for quantifying and comparing performance of the built environment. Otherwise, the concepts will have little effect in the real world. Among the choice of assessment methods, life-cycle analysis (LCA) is particularly interesting. LCA provides crucial insight into the nature of the problem, yet it is almost impossible to operationalize within the traditional design or policy-making process.

Life-cycle analysis in the building sector today

Much LCA research in the building sector to date has attempted to apply this method to buildings as discrete and specific entities. The results highlight many difficulties. It would seem that buildings are unlike any other product. A single building may comprise over 60 basic materials and around 2000 separate products, each with its own lifetime and unique production/repair/disposal processes. Data collection and allocation decisions for any particular building are far beyond the capability of most design teams or decision makers. A great many default assumptions are required, and even then the task is complex.

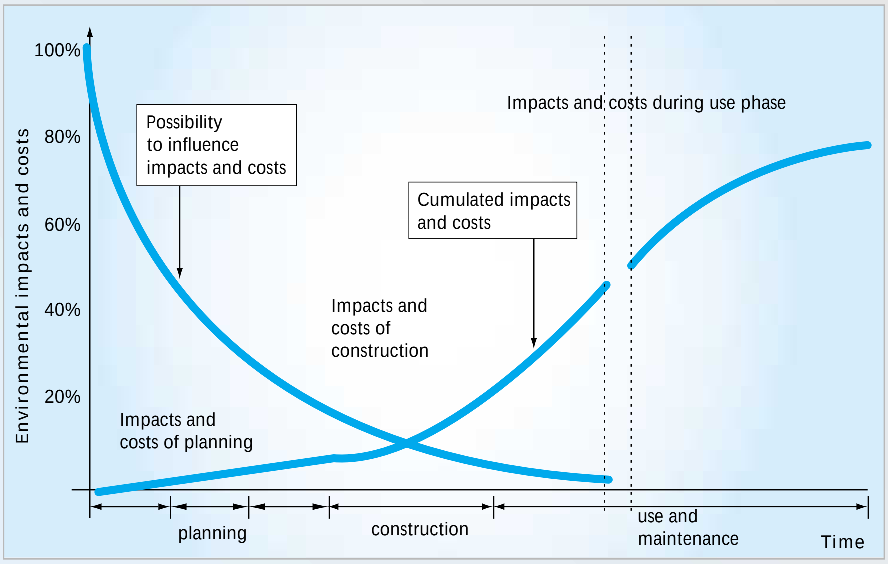
The long life of most buildings also means that, typically, more material and energy will be expended during the operation phase than in initial construction. Scenarios must be designed to predict the nature of these future investments, including estimated life spans and disposal routes for materials. Thus the majority of resource flows over the life cycle are influenced by highly speculative assumptions.

The site-specific nature of a building complicates application of LCA. Significant local impacts need to be considered, such as a building's effect on the urban microclimate, solar access for adjacent buildings, neighbourhood security, resiliency, diversity and amenities, and the loading of urban infrastructure systems and allocation of local ecological carrying capacity. By definition, a building also creates an indoor environment – an environment with a whole new list of potential impacts including on worker productivity and occupant security, comfort, safety and health.

For all these reasons, application of LCA to buildings has so far remained in the realm of research groups – along with a few valiant private sector firms that are pioneering LCA software and rating systems. Increasingly, however, LCA is seen as an educational and policy tool that is best applied to generic buildings and building stocks rather than to particular cases. And the focus of research is increasingly expanding from individual buildings to management of the built environment (defined as the construction, operation, renovation and final elimination of buildings, infrastructure and exterior surfaces). The advantage of expanding the focus is, firstly, that it provides an opportunity to capture the extremely important relationships (i.e. energy and mass flows) between and among buildings. In so doing, LCA can encourage the evolution of integrated systems, cascading of resources (where output/waste from one process becomes input for another) and the other elegant "system" solutions that help convert collections of buildings into sustainable urban ecologies.

Secondly, expanding the focus allows LCA to

Figure 1
Influence of design decisions on life-cycle impacts and costs of an average European or North American building



inform decision makers about key trade-offs among the broad range of performance objectives encompassed by sustainable development. For example, energy and mass flows within a neighbourhood may need to remain within boundaries. Too little, and the built environment suffers from neglect; too much change all at once, and cultural integrity may be destroyed.

LCA and the integrated design process

Whether LCA is applied to individual buildings or the entire built environment, the knowledge gained cannot easily be used without significant changes to the traditional planning and design process. In simple terms, what is required is an integrated design process (IDP) that reflects the trans-disciplinary nature of the built environment and encourages functional integration of long-term environmental performance with the many other sustainable development objectives. IDP involves creating a design or planning team with a wider range of technical experts, local stakeholders and partners than is normal – including individuals with knowledge of and responsibility for operations, maintenance, refurbishment and community relations. A facilitator may be needed to ensure successful communications, and to help experts and stakeholders negotiate the inevitable trade-offs.

IDP should engage a diversity of actors at very early stages of the project and use their expertise to influence seminal design decisions. As shown in Figure 1, the potential for influencing the full life-cycle performance is very high in the early stages of design and decreases dramatically as time goes by. In the early stages it is possible to find the synergies and out-of-the-box solutions needed to actually make sustainable development practical. Performance measurements or indicators can be adopted to serve as benchmarks for the project, and for use in identifying critical thresholds (or constraints) and setting ambitious targets. The entire design team may participate in an inspirational target-setting workshop at the beginning of a project, and the targets may continue to inform decisions concerning the project throughout its life cycle.

Transfer of insights from research to practice

For most projects, a complete LCA is unaffordable as long as it is not integrated with other tools such as quantity surveying or energy simulation. The following insights appear to have worldwide application despite variations in culture, climate and construction:

◆ The most environmentally friendly building is usually no building at all. For example, if a hospital building can be eliminated through policies for providing people care in their own homes, or if adaptive reuse of existing under-used facilities can eliminate the need for more office or plant, this would typically be a preferable approach.

◆ Understanding the system boundaries of LCA is critical for anyone attempting to compare results, or to learn from the research. A system boundary has the effect of limiting specific resource flows and emissions included in the assessment. Comparative international studies implementing different LCA tools show that most variations observed in the results derive from differences within the limits of the system – differences that were not always clear at the outset.

◆ Sensitivity analysis, when used skilfully, can dramatically reduce the scope of LCA as well as the corresponding amounts of data and work needed to arrive at a robust assessment of impacts. Sensitivity analysis may also indicate that products embodying toxic compounds such as the mercury in some lighting ballasts (i.e. devices to stabilize current) will typically have much greater life-cycle costs than less toxic options.

◆ LCA emphasizes the value of adaptive designs that continue to perform despite changes in building use and technology. Small upfront investments to enhance convertibility, flexibility and expandability can greatly reduce the costs of keeping structures functional over time. It is often easy to make significant reductions during the operating phase by investing in products and equipment that are more robust, as repair and replacement tend to provoke high energy and mass flows. Especially problematic are situations in which long-lived products are embedded in short-lived ones.

◆ A life-cycle perspective can reveal an interesting relationship between aesthetics and overall performance. Spaces and structures experienced by occupants as pleasing and life-enhancing are more likely to survive in the long term, despite losses in efficiency and functionality.

◆ LCA is intended to encourage trade-offs between each phase of the life cycle, rather than addressing each phase on its own. It is a common mistake to assume that LCA will result in reduction or minimization of embodied energy (and associated emissions) in a building or facility. In reality, the most effective strategy is often to increase embodied energy (more substantial foundations and veneers, additional insulation, more sophisticated envelopes that allow access to services) and thereby reduce more substantial impacts related to operation, refurbishment and replacement of the structure.

◆ Selection of interior finishes is critical. Finishes that are difficult to clean may require more aggressive cleaning products and more frequent cleaning, which in turn can substantially increase material and money flows and environmental effects. Finishes that "turn over" quickly can also accumulate substantial life-cycle flows.

◆ There are few magic bullets. Initially, designers will want to know what works and what doesn't – steel, concrete or wood? coal-fired electricity or diesel? The devil is in the details. Variations within one class of products often exceed variations between classes. Using average, out-of-date or default data for whole classes of materials and products can lump the best performing and most innovative with the worst, so that everyone is tarred with the same brush.

◆ Concrete always deserves special attention. In some projects, concrete alone can represent a majority of the embodied energy in the built environment. The disadvantage of concrete (i.e. its large impacts) can be compensated over a long lifetime (>100 years).

◆ It is very important that all LCA methods refer to both absolute and relative target values. In real design situations one rarely looks for the most environmentally friendly building, just as one rarely looks for the absolutely cheapest building. Evaluation of a building's design and its effective performance is always a matter of complex trade-offs.

Variations in LCA from one region to another

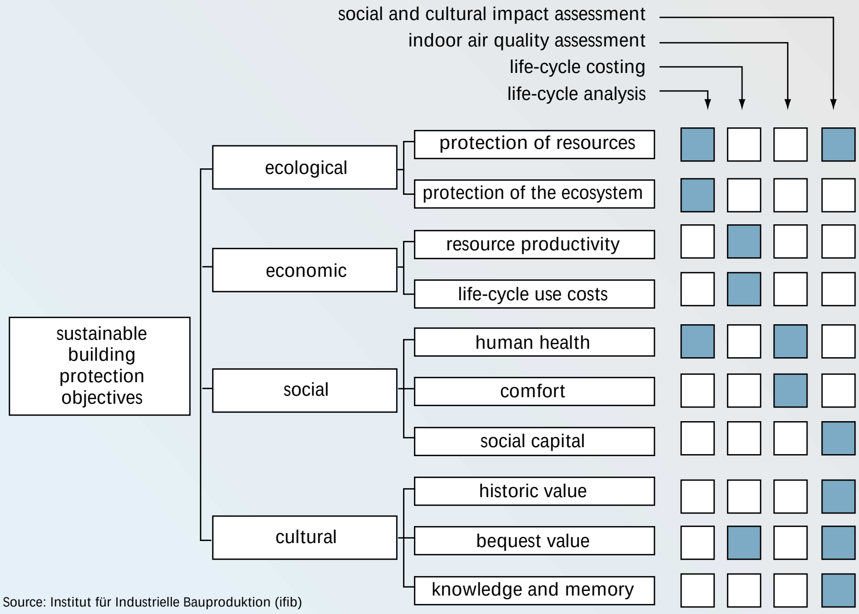
The use of standardized LCA methodology allows all locations to profit from a large body of research experience with establishing system limits, allocating inputs and outputs, and constructing a common database. A number of international organizations and public-private initiatives are now making progress towards this end. LCA calculations of absolute mass and energy quantities will eventually permit true comparisons of the global impacts of buildings in different countries. For example, the ecological footprint can be calculated for an office in Buenos Aires and compared with that of an office in Berlin. Further work on LCA tools may ultimately allow LCA applications to easily accommodate the highly variable local norms for impacts such as resource scarcity, ecological sensitivity, human health and personal security (Figures 2 and 3).

The scarcity of LCA applications worldwide limits opportunities for comparing results taking into account different climatic, industrial, social and cultural contexts. However, it is still possible to posit some general priorities with respect to LCA related policies in different parts of the globe.

European priorities

In Europe, research on environmentally friendly buildings has mainly been associated with new construction. LCA on the evolution of European building stocks suggests that the critical issues for sustainable development lie elsewhere, i.e. management of existing buildings, refurbishing of post World War II buildings and conservation of the complex qualities of historic towns. Future LCA applications are likely to focus on managing European building stock as a resource, which will replace nature as the principal resource in the long term. The key impacts are those related to energy consumed for heating and transport and to the human health effects of building materials. Because of the still long lifetime of buildings, and the predominance of environmental impacts in the use phase (mainly through energy consumption), the focus in the case of existing stock will downplay the impacts of construction and deconstruction. However, in the case of new low-energy buildings, all phases will receive equal attention. For both existing and new buildings (and the entire built environment) LCA will be used to implement and assess the new targets for factor ten reductions and "closed loop" material management.

Figure 2
LCA as part of the assessment of a sustainable building



Source: Institut für Industrielle Bauproduktion (ifib)

North American priorities

Unlike Europe, many urban areas in North America are rapidly growing and the existing stock has high turnover rates. Consequently, attention must be divided between existing and new. LCA will likely assist with the evolution of rating systems and certifications for both new and renovated buildings. It is to be hoped that LCA will also assist in adjusting such rating systems to reflect regional contexts.

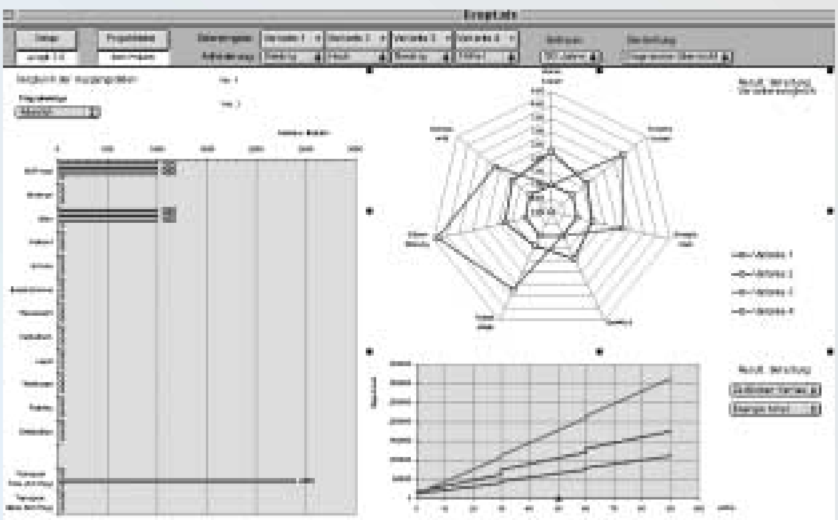
A priority for rapidly growing areas is to change the focus from individual buildings to the built environment, with consideration given to distributed, integrated infrastructure systems and "smart" land use patterns.

Another priority is improving buildings' operational lifetimes and maintenance cycles in the face of trends in the opposite direction. Durability and longevity are becoming especially important parameters in cities where building technology is undergoing rapid change and becoming increasingly complex. Vancouver, Canada, provides an example of what can go wrong. Water leakage in new condominium housing has reached disaster proportions, with > US$ 2,000,000,000 in repair and associated costs over the last five years. The combination of new assemblies and design details, out-of-date codes and regulations, and importation of flat-roof California style design features to a rainforest climate have all contributed to a costly surprise. Over half of new residential buildings have experienced failed envelopes within their first eight years. The increasing complexity of building systems, and a lack of monitoring and pre-trials, leave many growing urban areas susceptible to such surprises.

Rapidly industrializing countries

A common theme for all countries during rapid industrialization is under-pricing of natural resources and under-regulation of environmental protection, health and safety. LCA is an excellent tool for setting regulatory priorities in these areas, and for establishing appropriate fees and development charges. Another priority for LCA in industrializing countries is managing the pace of change. Many new economies prefer western building styles and technologies to the time-tested systems used in vernacular architecture. A life-cycle perspective helps give value to building styles and technologies that are resilient and long-lasting. A life-cycle perspective may also help reduce irreversible losses in cultural capital, as many

Figure 3
Example of an integrated life-cycle analysis (LCA) and life-cycle costing (LCC) method: in the spider three design solutions are compared according to ecological, energy and economic criteria (values take account of operation, embodied energy and transport)



Source: ECOPT (Erasmus Center for Optimization of Public Transport) - ifib.

countries are losing precious architectural heritage in the rush towards industrialization.

Another priority for industrializing countries is to reduce impacts associated with the high volume of material accumulating in the built environment. Innovative building practices are needed to reduce the excessive amounts of heavy masonry used in construction, and to convert some of the dirty energy systems used for producing materials.

Developing countries

LCA has a different role where urban poverty and lack of affordable and healthy housing are central societal problems. In these situations the objective of reducing life-cycle impacts is secondary to that of restoring dignity and security to families. Many residential building projects are not subject to a controlled design process and regulation may be haphazard. Thus the priority for LCA is to set targets in those areas most amenable to regional and national policy initiatives, and to otherwise support improvements in industrial process innovation and environmental protection (e.g. environmental management systems). Life-cycle perspectives in these economies will emphasize problems created by the introduction of toxic substances and the importance of environmental protection during land development and construction phases.

New directions for LCA tools

When practising professionals are able to apply LCA easily to the built environment, this will likely be as a result of improvements to LCA tools. One promising solution in industrialized building economies would be to combine tools for LCA with those used for quantity surveying, so as to construct a common basis for LCA, cost estimation and tender operations. Through sharing basic data and tools, the supplementary effort required for LCA analysis and interpretation may become acceptable.

A blueprint for green building economics

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Green building has rapidly gained momentum as a design protocol and measurement standard for buildings' environmental performance. Though many precepts of sustainable building were established thousands of years ago, this concept has only been defined and integrated into the global building industry since the late 1980s.

Green building rating systems in various countries provide the best definition of a "green building". In many countries green building activity has taken place mostly in the public sector. The cost of funds for government is low, and the time horizon for the average life of a public building is long. Buildings are typically owned, financed, operated and occupied by a governmental agency. Wearing these multiple hats makes it easier for governmental owners to design buildings to maximize their performance and occupant health on a long-term perspective.

Green building is just beginning to gain momentum in the private sector. Only a few visionary firms like Ford Motor, Gap, Wal-Mart and Hines Development have undertaken projects. The main barrier is the difficulty of quantifying economic benefits. In addition, many buildings are speculative, contributing to a short-term (cheapest first cost) owner orientation.

The many economic opportunities (and the rationale) for green building in the private sector are outlined below, following the flow of a developer's typical financial analysis areas for a new development building.

Project cost

Three areas contribute to a project's total project cost: site acquisition, and direct and indirect construction costs.

Site acquisition costs

It is important to purchase a property that will enhance the ability to create a high-quality green building. LEED, the US green building rating system, provides credits for proximity to public transportation, urban infill and reduced site disturbance. Solar access is important, as is natural ventilation potential and good ambient air quality. Sensitivity to water quality and to run-off minimization is also critical. If demolition is required, it is important that a majority of the materials are diverted from landfill for environmental reasons. Some systems reward building reuse and brownfield redevelopment.

It has not been established that a green site is more expensive; this could be a matter of careful inspection when looking at prospective properties. Case studies show that diversion of construction and demolition waste from landfill is cost-effective.

Some cities even provide a density and/or height bonus for green buildings. Increased space can more than compensate for any extra cost of developing a green building.

Direct construction costs

Numerous examples show that green building does not cost more. The new DPR Construction building in Sacramento, California, is expected to achieve a LEED Silver rating at an added cost of less than 1%. DPR estimates the payback period at less than two years.

The city of Seattle, Oregon, originally allocated a 4% cost increase to achieve a similar rating. However, its extensive project experience (over 30 buildings at a minimum LEED Silver level) has effectively lowered the cost increase to below 1%.

The Ridgehaven Building in San Diego, California, achieved an energy efficiency improvement from the Energy Code requirement of 53%. The incremental add was about 4%; most of the cost increase was funded by the local utility. The internal rate of return on the net investment was 57%. The net green building cost did not take into consideration the significant downsizing of the mechanical system (about 30% load reduction) and similar reductions in the quantity of lighting fixtures and fixture sizes. Therefore, the overall net cost was zero.

Indirect construction costs

As green building continues to expand, almost all architectural and engineering firms are entering the field. Green building is rapidly becoming part of standard practice, as owners increasingly require this methodology as part of a building's design. In the early years design professionals charged a premium to provide green building services. However, as the green building market rapidly expands, extra fees charged for these services are declining. Some firms are now offering them at no extra charge, and this will soon be the norm.

Another indirect cost may be that of certification. In the US, for example, if a project is formally certified by the Green Building Council (USGBC) fees are charged depending on building size.

Still another indirect cost of construction is tenant lease-up contingency. It has been shown that a green building receives added publicity. Some projects, like New York City's Four Times Square, have been the subject of hundreds of articles. This can result in a higher level of perceived building value. Educating brokers and their tenants about the merits of green building can result in a more rapid building lease-up period. The green emphasis can also assist negotiations with local governments on building permit and land use approvals, reducing land carry costs.

Income and expenses

Income

Because green building is so new, sufficient data have not been collected to

Essentially, anyone attempting to describe a building would reference a multi-purpose catalogue. All the elements in the catalogue would be composed of building process specifications. For each building process specification, it would be possible to identify each of the material processes involved and describe them in terms of quantities of materials used (including all auxiliary materials and waste) and the quantities of tools and machines used (including their energy consumption and maintenance). In this way data could be aggregated for all relevant processes that make up a building and used to estimate total life-cycle mass flow, primary energy consumption, impacts and other indicators of interest. What this formula appears to provide is a practical way to analyze economic and ecological consequences of design decisions over the entire life cycle of the built environment. Time will tell.

On the other hand, it could be helpful for designers, builders and owners in developing countries to dispose of very simple LCA and LCC (life-cycle costing) tools comprising the basic production, transport and use process (cooking, water cleaning, etc.). This could allow fixing strategies for optimal use of scarce resources such as energy intensive new building materials (cement, glass, metals) as well as fuel for transport.

Life-cycle analysis is certainly a necessary (but insufficient) tool for all efforts aimed at achieving more sustainable societies all over the world.

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show that it can increase rental rates. However, it is logical that a building is worth more if it has lower operating expenses for tenants, enhanced daylighting, operable windows, improved occupant comfort and individual control, better air quality, and dozens of other positive tenant features – which will be considered in setting the rental rate.

It is a matter of marketing by the owner and broker to communicate this enhanced value to prospective tenants. There is enormous precedent in other areas, where the consumer pays more for higher value. This occurs every time we buy a car or appliance. This is also true of office and retail space, and even of housing. An "A" level building, for example, rents at higher rates than a "B" building. As green building is adopted in the mainstream, it would be expected to become part of the definition of an "A" building.

Another income benefit associated with green building will be lower vacancy rates. Higher quality buildings have historically shown lower vacancy rates. Tenants prefer to renew their leases, as they appreciate a building with enhanced comfort and health and productivity for their employees. Proximity to public transport is another benefit, as well as showers and bike racks. An underfloor air distribution system provides greater comfort and dramatically reduces tenants' cost of churn (cost of office occupant relocations) – estimated at US$ 2500 per incident.

Expenses

It has been demonstrated that green buildings' operating expenses are significantly lower. Energy can be reduced by 30-50%. Water consumption can be reduced by over 30% or even more. Repairs and maintenance can be reduced, as well as landfill charges associated with a lower level of waste.

Improved indoor air quality can lead to reduced owner liability. This contributes to reduced expenses and even to lower insurance premiums. Moreover, it is anticipated that insurance companies may soon provide an insurance cost reduction for green buildings. In time they may also make certification a prerequisite for obtaining insurance.

Green building is also an effective risk management strategy for property managers: improved air quality, lower energy, water and waste costs, and longer building system lives.

The net result of higher income and lower expenses is improved project net cash flow.

Financing and equity

A green building with increased building net operating income will achieve a higher building valuation. This can result in a higher loan amount and future sales price. Project equity requirements are reduced accordingly. Additional debt, however, does increase the owner's risk.

In time it is envisioned that banks will offer green loans based on certification, lowering the interest rate and/or increasing the allowable loan to cost or value ratio. Once this becomes the norm, some banks may progress to ultimately requiring a minimum green rating as a qualification for the loan. This will accelerate green building more than other measures.

Some projects are beginning to attract investors interested in participating in a green building project. They understand the opportunity for improved financial return, along with a social dividend. In times when it is difficult to attract equity for a project, green buildings will have an advantage.

Green buildings can qualify for subsidies and tax credits. In the United States, the State of New York passed the first green building tax credit. Some utilities offer rebates and green building financing. They are evaluating the potential of financing and even owning on-site distributed energy generation systems for private and publicly owned properties.

Return on equity/project valuation

The net result of increased income, lower expenses, and any reductions in financing is a more profitable building. As property appraisers learn more about green buildings, they are likely to incorporate relative greenness in the valuation. Buildings with a green rating may qualify for a higher capitalization rate than a non-green one.

Even a 1/2% of capitalization rate improvement can equate to significantly higher building value upon sale or refinance. Adding this amount to the increase associated with improved net operating income can materially improve the overall project return on investment.

Conclusion

It is not hard to comprehend that a healthy, resource-efficient and daylighted building is better than one that does not have optimal air quality, is highly resource consumptive, and is very dependent on cheap power. It is only a matter of time until banks, insurance companies and tenants better understand the benefits and value of green building, creating a shift in market demand. When this occurs, owners who have embraced these principles will greatly benefit. Even if this does not happen, they will prosper owing to lower expenses, greater tenant satisfaction and the resulting enhanced financial yield.

When the decision to go green is analyzed, the question should not be solely the impact on first cost, but also the overall change in the building's return on investment. This is best reviewed as a projected net present value or internal rate of return over the life of the asset. Green building is an economic responsibility to our investors, and a social one to society. It is rooted in the definition of value, quality and performance over the life of the asset.

For more information, see: www.worldbuild.com; www.usgbc.org; www.worldgbc.org.

Drivers for sustainable construction

Sustainable Development Task Force, International Federation of Consulting Engineers (FIDIC), World Trade Centre II, Geneva Airport, PO Box 311, CH-1215 Geneva 15, Switzerland (fidic@fidic.org)

Summary

The potential impacts of changing to sustainable construction are related to construction industry demands, needs and drivers and to the acceptance of sustainability concepts. These impacts will differ from one country to another. In this article consideration is given (in terms of an increasingly broader perspective) to activities in the main sectors where the construction industry is called upon to make a difference: infrastructure, commercial property and housing. The challenge for the industry is to identify – in both developed and developing countries – aspects of sustainable construction that can realistically be addressed and areas where action can make a significant contribution to achieving sustainability. Clients increasingly recognize the positive economic outcomes of sustainability as a driver for investment decisions.

Resumé

Les effets potentiels d'une évolution vers le développement durable de l'industrie de la construction sont fonction des demandes, des besoins et des moteurs de cette industrie, ainsi que du degré d'acceptation des concepts de développement durable. Ces effets varieront d'un pays à l'autre. L'article s'intéresse (en termes d'élargissement des perspectives) aux activités des principaux secteurs où l'industrie de la construction devrait faire la différence : infrastructures, locaux commerciaux et logements. La gageure, pour l'industrie, est de discerner, aussi bien dans les pays développés que dans les pays en développement, les aspects qui peuvent raisonnablement être abordés et les domaines où une action apportera une contribution significative au développement durable. Les clients reconnaissent de plus en plus les effets économiques positifs du développement durable, à savoir son rôle moteur dans les décisions d'investissement.

Resumen

El impacto potencial de un cambio a la construcción sostenible se analiza en relación con las exigencias, necesidades e incentivos de la industria de la construcción y de la aceptación de ésta de conceptos de sostenibilidad. El impacto varía de un país a otro. En el artículo, se toman en consideración (en términos de una perspectiva cada vez más amplia) las actividades de los principales sectores en los que la industria de la construcción desempeña un papel importante: infraestructura, propiedad comercial y vivienda. El reto para la industria es identificar —en países desarrollados y en desarrollo— los aspectos de la construcción sostenible que se pueden tratar de manera realista y las áreas en que la acción aportará una contribución significativa para lograr la sostenibilidad. Más y más clientes reconocen los resultados económicos positivos del la sostenibilidad como una incentivo para decisiones de inversión.

Demand for construction services is divided fairly equally between the private and public sectors. In the developing world this demand relates mainly to new infrastructure (schools, hospitals, roads) and housing. In the developed world it relates mainly to housing, roads and non-residential fixed investment.

The construction industry's "cradle-to-grave" activities in the built environment lead to important, well documented global environmental impacts and demands on natural resources – especially for housing, infrastructure and utility servicing provision, which are very resource-intensive.

The industry has a responsibility to minimize negative environmental and social impacts and maximize positive contributions. It is potentially the main single-sector contributor to achieving sustainable development.

The potential impacts of change are different in different countries. Developed countries could devote greater attention to creating more sustainable assets through upgrading existing facilities using innovative technologies for energy and material savings. Developing countries are still under construction. They have a low degree of industrialization, so that construction activities are among the main factors affecting the biophysical environment. These countries are more likely to focus on the social equality and economic sustainability of infrastructure provision.

The challenge for the construction sector is to identify those aspects of sustainable construction that can realistically be addressed and where action might have a significant impact on sustainability.

Industry activities concerned with sustainability

The impacts of most construction projects begin well before the conventional project cycle and end well after the cycle is over. Activities are linked to allied sectors and industries, starting with the extraction and processing of raw materials, extending through the supply of inputs such as water, energy and construction components and equipment, and terminating in demolition and the disposal of wastes.

These activities are loosely grouped into what we might call a hierarchy of perspectives, starting with operations and maintenance, on-site and off-site activities, and moving to sector-wide activities and activities involving the broad range of processes for realizing the built environment.

The two industry subsectors responsible for managing activities are physical construction and knowledge-based construction services. The former, generally undertaken by contractors, brings together labour, material and equipment in order to translate specifications produced by knowledge-based service suppliers into physical activities. The design and specification side of the industry includes architectural and engineering design services used throughout the project cycle. These services require general and specialized engineering and other technical, scientific and economic skills needed to optimize investment in all its forms: its choice, its technical process of execution, and its management. For the sector as a whole, the challenge is to translate the benefits of sustainability into a project approach that clients can appreciate and support.

In general terms, the permitting requirements for construction activities are becoming more comprehensive on a worldwide basis, and implementation of sustainability concepts at the more operational levels of the industry's activity is relatively straightforward.

It becomes much more difficult to identify pragmatic drivers for change as one moves from operational and off-site project activities towards the sectoral and built-environment perspectives of sustainable construction.

At present, the construction industry seems unaware of its potential to reshape demand through product redesign. This is largely because the industry is preoccupied – and rightly so – by the enormous unsatisfied demand for basic infrastructure, and by the fact that in the current system it is the clients and owners who decide.

Sustainable procurement

National governments and contracting authorities together constitute the construction industry's largest client, especially for infrastructure supply. The regulatory framework that controls the market for engineering and design activities, and the accompanying national strategies and action plans (notably national and Local Agenda 21 processes) are being adjusted to address the public's desire for sustainable development. National priorities and rules now generally require integration of sustainable development when clients formulate a demand for services. For example, environmental impact assessments are carried out for an increasingly wider variety of investment projects, and environmental codes now place a greater responsibility on property owners.

Regulations governing public procurement aim to guarantee fair and transparent competition to obtain the best quality-price ratio with optimum use of public funds. Policy considerations, important as they may be, should generally not be a factor in decisions concerning the award of procurement contracts.

For procurement by tendering (the most common practice) the choice of the winning bid is simple in principle: the most economically advantageous offer that is responsive is awarded the contract. Award criteria other than price (e.g. quality, performance, time, ingenuity and environmental effects) should be expressed in monetary terms to the extent practicable.

When a design and construct responsibility is contracted out against a design specification that defines "fitness for purpose", there are some measurable parameters. However, many parameters that respond to quality (e.g. durability and maintenance) and to function and environment remain subjective, difficult to measure, and thus difficult to award profit against. These considerations require continuous discussion to set actionable but balanced standards and specifications combining the objectives of public procurement with environmental and social policies.

European legislation already accepts that environmental issues can be used as an award criterion in a contract, provided there is economic advantage. Some argue that procurement directives should go much further by allowing the contracting authority to use as criteria aspects linked to general social or environmental objectives (e.g. unemployment campaigns) provided the criteria are consistent with legal principles, notably non-discrimination.

However, it is not the role of a contract between two parties that is enforced by each party to incorporate the sustainability obligations of the two parties with respect to a third party, namely society at large.

First, the parties are bound by law to respect environmental and social obligations independent of the contract.

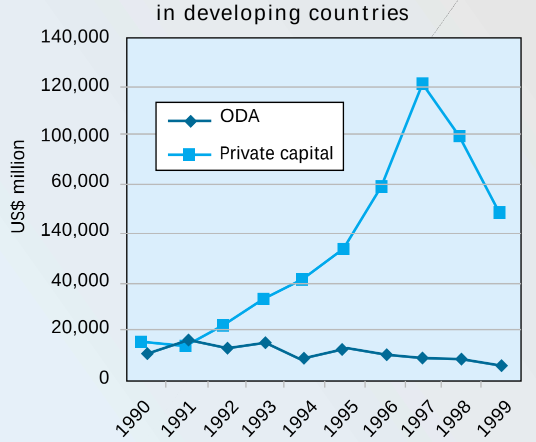
Second, public authorities can opt for environmentally sound requirements by specifying what is required in the call for tenders. They can procure services on the basis of the economically most advantageous tender, balancing price, quality and life-cycle costs, for which quality assessment criteria include sustainability factors. Local authorities, for example, are encouraged to apply the principles of ecological land-use planning. Similar expectations are placed on the military, the health sector, and other services areas controlled directly by government. However, even life-cycle costs are often left out of the equation, let alone sustainability considerations.

Innovative methods of project delivery

Experience has shown that attempts to secure sustainability goals by imposing constraints and requirements on a particular aspect of the project cycle are ineffective and generally resisted.

At the same time, the construction industry (aware that traditional project delivery by competitive tendering is not necessarily the most efficient method) is moving away from the simple and confined goals of cost and time for construction to focus on the macro issues of overall project outcomes, where the outcomes are used as goals for all project participants. This shift comes from strictly commercial reasons (e.g. elimination of disputes) and the understanding that it should be possible to take a more global view.

Figure 1
ODA and private capital flows to infrastructure in developing countries



Report of the Third United Nations Conference on the Least Developed Countries, LDCIII, Infrastructure Development Session, Brussels, 19 May 2001

It was initially felt that contractual relationships could be replaced by long-term relationships based on the outcome (determined by clear measurement of performance) of a process involving sustained improvements in quality and efficiency.

Such arrangements are not sufficiently rigorous, so other methods based on outcome-based delivery are being tried. In the partnering of project teams, project delivery focuses on a project business plan and compares this to the project outcome, apportioning profit to the delivering parties according to their ability to exceed the plan's requirements. The aim is for team members to share in success, in line with the value they add for the client. However, partnering has had limited success because it relies on best endeavours and acts of faith: partners simply tell each other that they will act reasonably and fairly while expressly disavowing any legal obligation to do so. Instead, it has opened the way to consideration of more efficient project delivery methods for complex projects based on aligning incentives.

Among the most widely used methods are alliance contracting (alliancing) and engineer-procure-construct-manage, a producer-controlled turnkey undertaking that provides greater competition over costs at the physical construction stage as the client works in close cooperation with a project management team. It is believed, but not yet proven, that alliancing and similar types of contracts should facilitate proper recognition of sustainability performance in the selection process.

It is also felt that the same global approach to implementing sustainability, using new modes of project delivery, is needed for smaller, community-based projects that seek increased public and stakeholder participation in the planning, implementation, monitoring and review of projects.

These new modes will not be based on alliancing and the like, which focus on relatively large-scale projects in developed countries. Public-private partnerships (PPPs) are being explored as a possible delivery mode. PPPs aim to help meet infrastructure needs by promoting private sector involvement. Experience has repeatedly shown the overriding importance of contractual terms, regulations, bidding procedures and market structure. Thus it is likely that developing the new modes will require very careful evaluation of all phases of the project delivery cycle. Progress is slow, indicating that it will be an enormous challenge to implement broad PPP concepts on a relatively small scale with relatively unsophisticated partners. In addition, private funding of infrastructure still only represents 10% of the total in developing countries, so there is little momentum for exploiting fully the possibilities.

Infrastructure demand

Analyses of the demand for infrastructure generally focus on the main components, i.e. telecommunications, power supply, land-based transport, and water and sanitation. In Latin America, for example, power infrastructure accounts for close to one-half of total infrastructure gross investment, followed by transport, telecommunications and water and sanitation.

Structural change in an economy, and income growth, increase the demand for infrastructure. The World Bank estimates that the investments needed for Latin America should amount to US$ 57 billion, about 2.7% of Latin America's GDP in 2000-5. Most of this amount would be for power, followed by roads and telecommunications.

The public sector's share of gross domestic fixed investment in the region was about US$ 37 billion in 2000. Given that not all of this investment is available for infrastructure financing, infrastructure investment needs will have to be foregone or made up by the private sector. The same is true elsewhere in the developing world.

Private financing for infrastructure has surged worldwide in recent years. Annual private capital flows to developing country infrastructure projects were similar in magnitude to official development assistance (ODA) in 1990. They then grew more than eightfold, reaching US$ 120 billion in 1997. However, they have proved to be volatile, with 80% going to only six upper middle-income countries. Financial crisis in the 1990s more than halved private capital flows to the infrastructure sector after 1997 (Figure 1).

Less than 1% of private capital flowed to less-developed countries, where ODA remains the dominant source of infrastructure finance (US$ 35 billion over the past decade, compared with less than US$ 5 billion of private capital).

Overall, 43% of private capital went to telecommunications, 32% to energy, 19% to transport, and only 5% to water and sanitation. In regions such as Latin America, which are dominated by countries that attract private capital, transport and energy were inversed. More importantly, private investment covers about half the investment demands for roads and only a fraction of what is needed for power and water and sanitation. The situation is much more serious in regions that attract relatively little investment, either private funds or ODA.

In a regime of shortfall, anything perceived to be more expensive will be ignored. Unfortunately, for many of the world's governments and private clients sustainability falls into that category.

Roads

Recent World Bank and World Business Council for Sustainable Development reports show a strong relation between the level of economic development and levels of motorization, road provision and distance travelled. Vehicle ownership increases with income, and estimated ownership saturation levels are well above currently observed levels, with little evidence that ownership slows in countries at high income levels (Figure 2). The same is true for distance travelled. Road provision at the national level is also very responsive to income, especially for paved roads, and very consistent across countries even though provided by government. In other words, overall demand for roads (ignoring the complex case of cities) invariably increases and obeys the same laws everywhere. The extent to which government can be a driver for change by moderating demand for infrastructure is probably limited if experience with roads is any indication.

Commercial property

The commercial property sector faces profound change in the developed world.

First, greater recognition of the differentiated role of buildings and space as productive assets (as opposed to crude containers) will drive demand.

Second, to reduce repair and maintenance there will be an increase in investment for commercial and industrial facilities that are designed and built as an industrial product for a single purpose, and that are built to last for a limited period before major refurbishment or dismantling.

Third, the combination of information technology and the growth in small companies providing business services may cause re-colonization of obsolescent, low-grade space.

Fourth, to maintain profitability businesses will have to work their assets harder, including buildings and other constructed facilities; assets must deliver more value.

Finally, major firms and asset managers with significant property portfolios are increasingly requiring suppliers, contractors and professional advisors to take their sustainability policies into account when they build or manage property in order to minimize environmental impacts and to contribute positively to society. This trend is accelerated by legislation such as the UK's 1999 Pensions Act requiring occupational pension funds to explain how they factor social and environmental issues into investments.

The fact that the main drivers for change remain largely economic is illustrated by a recent survey of the UK property sector, which showed that firms invest in urban regeneration for the same reasons they invest in normal property. The main factors are above-average perceived total returns and security of investment. Factors such as competitor behaviour, past experience, social and community involvement, and image were much less important.

The problem is currently that drivers for energy and resource efficiency and costs savings, especially in retrofitting and refurbishment, are not being translated to the less-developed world, with the exception of a handful of high-profile international companies reportedly anxious to present the right image to international investors and pressure groups. Very few companies are responding to fundamentals such as the impacts of climate change and resource limitations on the bottom line. These pioneers aim to set an example for a more radical change in thinking.

Housing

Housing investment typically accounts for 2-8% of GNP and housing services for an additional 5-10%. Some 56% of Europeans and 65% of North Americans live in owner-occupied dwellings. The remainder can be divided into the private rental sector and social housing. Every fifth apartment in Europe is rented from the social housing sector. Over half (52%) of the EU housing stock consists of one-family houses; there are slightly fewer (72 million) dwellings in buildings with more than one apartment.

The interplay of supply and demand determines the housing market. However, unlike road provision, housing conditions do not systematically improve with economic growth and development due to policy differences across cities and countries.

Reorganization of social housing provision and financing may change the balance of demand, with social housing accounting for an increased proportion of all housing. But given the tendency for reduced investment by government in areas that can be adequately supplied by the private sector, predictions of an increase in social housing are uncertain,.

Historically, most financing for sustainable housing comes from individuals with high net worth rather than from banks and traditional investors. Sustainable construction at the moment is still driven by the early adopters, mostly homeowners with enough private financing to pay for alternatives not supported by the financing issues. Here the drivers are related to the search for an alternative lifestyle.

But a shift appears to have begun. Private homeowners in the developed world perceive most of the value of their homes in terms of its location (40%). Functionality accounts for a similar perceived value, followed by image (15%) and services (5%). The market will respond when owners accept that sustainable construction increases functional value by being more durable, economical and efficient to run, healthier and more comfortable. In the United States institutional and investor resistance to environmentally responsible housing development is reported to be eroding. It is increasingly claimed that investors can expect the same return as on any other equivalent investment. The main barriers are seen to be financial, along with zoning regulations and poor acceptance by authorities of novel designs owing to unclear specifications.

Surveys suggest that there will be no substantial change in the nature of the aggregate demand for housing in the developed world in the near term, unless future changes in planning regulations severely restrict the availability of land for development or the price performance of new houses improves dramatically. The trend to sustainable construction in private housing that requires both a suitable location near transport and performance improvements will therefore be gradual.

Informal urban housing

Demand for affordable housing in the developing world has become so great that there is hardly any spare capacity to be directed to the other levels of sustainability, especially opportunities for the formal construction sector.

Low-cost urban housing in most developing countries is characterized by rapid growth of slums and unauthorized settlements (between 20-30% of new growth in cities). In low and low-middle income countries, 30-70% of urban housing stock is illegal or unauthorized since either land ownership laws or building and planning laws have not been followed.

Because land suitable for settlement is scarce and/or expensive, informal settlements are often sited in hazardous locations where people experience not only threats to health due to poor quality housing, water supply, sanitation and access to social services, but also a host of other problems.

Relative to developed countries, housing policies disproportionately affect the cost, availability, quality and production of informal housing since they extend to areas not normally subject to control, such as security of tenure and asset security for long-term financing.

Positive drivers for change are labour-intensive construction methods, locally sourced materials, and highly structured, internally networked and mutually supportive communities.

Low-cost urban housing

The informal sector is the main producer of housing stock in most developing countries. Much of this stock is based on community-based delivery processes. In many developing countries families build a significant number of houses, normally with help from friends.

Public sector low-cost housing produced by conventional construction processes is generally characterized by doubtful quality, unimaginative planning and design, low market image, high client dissatisfaction, poor land management, poor siting and low expectations of profit.

The situation is no better in the case of private sector low-cost housing. Progammes aim at low initial cost per unit delivered, with minimal consideration of the life-cycle cost. Such properties are scarcely ever integrated into the conventional property market, as they are perceived to be of inferior quality and with high financial risks.

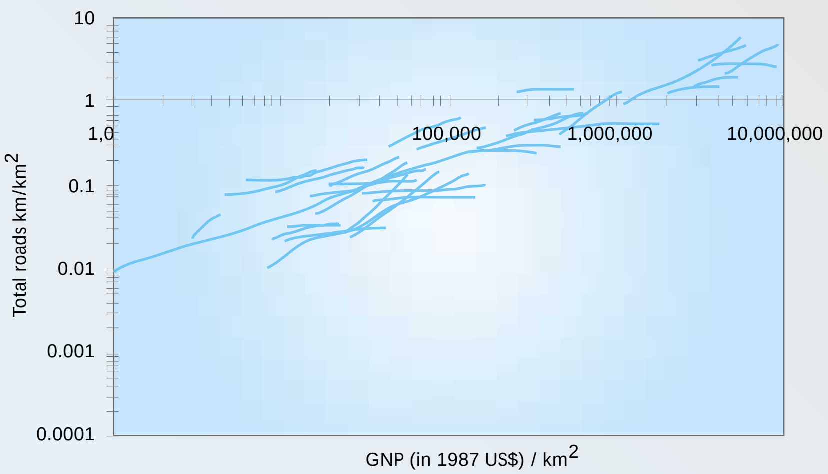
According to the report *Agenda 21 for Sustainable Construction in Developing Countries*, "It is now generally accepted that for housing to be sustainable in developing countries, programmes have to adopt a holistic perspective and include issues such as urban design, urban greening and the provision of social infrastructure such as schools and clinics. Housing cannot be seen as a product to be fabricated and delivered, but as an enabling and empowering process. This integrated concept of housing as part of the urban tissue of a city is not often contemplated by the construction industry, yet it is one of the most pressing problems of the developing world."

Innovative project delivery systems have shown themselves capable of reaching the poorest sections of the population. Among these systems are construction based on the collective and organized efforts of the community, and projects managed by housing cooperatives or associations that work on a non-profit or cost-covering basis.

The most effective participative systems have proved to be self-managed popular cooperatives, where the community has financial control of the project, and contracts for private-sector technical consulting services for the development of the building project and its execution.

The total indirect costs of building are some 45% less than the total cost of conventional construction, and the quality of construction is higher. Differences are accounted for by reduced waste and the diversity of architectural solutions resulting from participation of the cooperative workers in the planning and execution.

Figure 2
Changes in total road network density in 50 countries (1970-90)



Source: G.K. Ingram and Zhi Liu, *Motorization and Road Provision in Countries and Cities*, The World Bank, 2002

Motivation for improving low-income housing in the majority of developing countries relates to overcrowding, insecurity, vulnerability to disasters, poor siting, poor quality, poor ventilation and design, sluggish supply, land and housing that are unaffordable compared to income levels, and strained physical infrastructure and social services.

Governments are trying to support the low-cost housing market, but the realities of market forces are limiting adoption. Pilot projects have been mainly driven by agencies and non-governmental organizations keen to import an approach or a technology, and supported by donor aid. The focus is generally on energy efficiency, as that is where the international funding lies. Water management is of critical importance, but it is receiving considerably less attention.

The main drivers are improved health (reduced indoor air pollution) and poverty alleviation (less money spent on energy means more money to spend on education and nutrition).

Conclusions

The construction industry has a huge capacity to participate in the development of a sustainable built and natural environment. It makes pragmatic efforts to instil and extend sustainable concepts at the project level, with private and public clients, in areas of activity that it can influence. Clients are increasingly recognizing the positive economic outcomes of sustainability as a driver for investment decisions. In the developing world, adequately financed innovative project delivery systems have the potential to meet urgent housing needs on a sustainable basis. However, infrastructure shortfalls and seemingly entrenched consumption patterns challenge the development and implementation of adequate governmental procurement policies.

FIDIC (the International Federation of Consulting Engineers) represents the business interests of suppliers of technology-based intellectual services for the built and natural environment. The FIDIC Sustainable Development Task Force is charged with implementing the federation's strategy and action plan for sustainable development.

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One million sustainable homes

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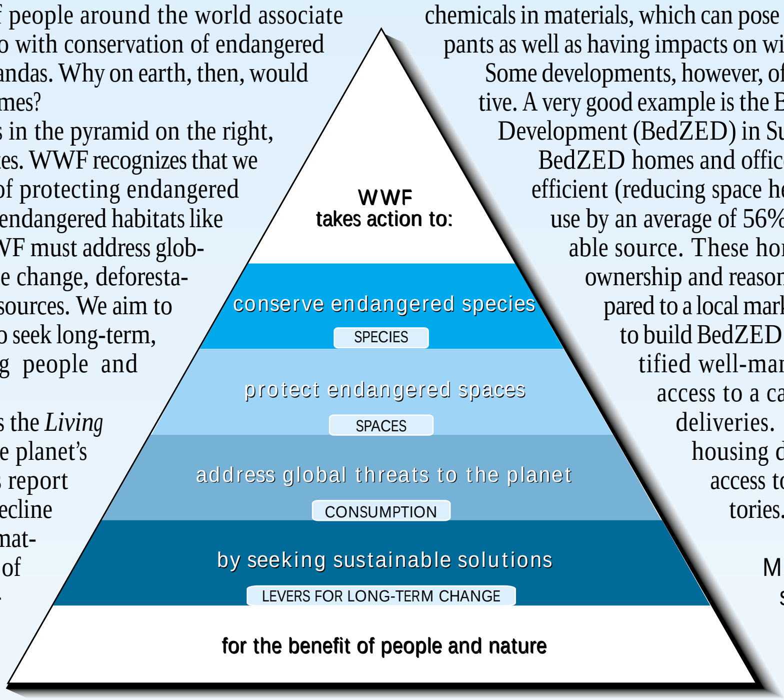
Not surprisingly, the majority of people around the world associate WWF and our famous panda logo with conservation of endangered species such as tigers, rhinos and pandas. Why on earth, then, would WWF be interested in people's homes?

The answer to this question lies in the pyramid on the right, which illustrates how WWF operates. WWF recognizes that we can only achieve our vital work of protecting endangered species if we take action to protect endangered habitats like forests and oceans. To do this, WWF must address global threats to nature such as climate change, deforestation and wasteful use of natural resources. We aim to do this by working with partners to seek long-term, sustainable solutions benefiting people and nature.



Every two years WWF produces the *Living Planet Report*, which measures the planet's "health".[1] With each update this report indicates a continuing dramatic decline in the number of species and a dramatic rise in the rate of consumption of natural resources and levels of pollution. The report also measures the "ecological footprint" of individual nations and, shockingly, tells us that if everyone around the world consumed natural resources and generated CO_2 at the rate people currently do in the UK we would need three planets to support us.

Unfortunately, the majority of homes in the UK have significant negative impacts on the environment. These include direct impacts with respect to a number of key WWF priorities including climate change, protection of forests and freshwater environments and reducing the use of toxic chemicals. For example, typical newly built homes in the UK use three and a half times more energy than those in Denmark and Germany.[2] In social terms, this clearly has consequences for people who have difficulty affording to heat their homes properly. According to the Joseph Rowntree Foundation:

"Britain has around 40,000 more deaths during December and March….which is a larger 'winter excess' than in most other European countries, including Scandinavia. This is in spite of the fact that Britain has comparatively mild winters….part of the explanation may lie with Britain's ageing housing stock, which….may provide less protection against the cold."[3]

In environmental terms, housing in the UK contributes around 27% of total CO_2 emissions associated with energy use. Domestic energy use is projected to rise by 6% by 2010. It is therefore essential to reduce emissions from new and existing houses if we are to mitigate some of the worst effects of climate change.

Furthermore, up to 70% of timber used in the UK goes into construction and a high proportion is used for housing. The housing industry must demand timber from well-managed, independently certified sources if we are to halt and reverse threats to forests around the world – 14.6 million hectares of natural forest are lost each year, a rate of 30 hectares every minute.[4]

Other impacts related to construction of new homes include quarrying to provide aggregates, wasteful use of water, and widespread use of toxic chemicals in materials, which can pose significant health risks for occupants as well as having impacts on wildlife.

Some developments, however, offer a more "sustainable" alternative. A very good example is the Beddington Zero (fossil) Energy Development (BedZED) in Surrey.[5]

BedZED homes and offices are highly energy- and water-efficient (reducing space heating needs by 90% and water use by an average of 56%) and use energy from a renewable source. These homes are a mix of social, shared ownership and reasonably priced units for sale (compared to a local market average). Most materials used to build BedZED were from local, recycled or certified well-managed sources. Residents have access to a car pool and local organic food deliveries. Although it is a high-density housing development, all residents have access to private gardens and conservatories.

Mainstreaming sustainable homes

Unfortunately, developments such as BedZED are currently the exception rather than the rule in the UK. This is why, in December 2001, WWF-UK invited the government to make a public commitment to develop one million sustainable homes in this country. WWF recognized that the government could not deliver such a commitment alone. The support of a wide range of stakeholders would be needed, including representatives of the house building and construction industry, the investment community, local authorities and planners, consumers and NGOs. WWF has a strong track record of bringing together businesses and governments to seek solutions that bring social, environmental and economic benefits. Our success in this area has been shown through our work on sustainable forestry, fisheries and rural development.

WWF initiated an independently facilitated dialogue process designed to identify the barriers to sustainable homes and ways to overcome them, to build on best practice and lessons learned to date, and to develop consensus among a wide range of stakeholders. A consultation questionnaire was sent to over 350 stakeholders, and we held a multi-stakeholder workshop with key organizations including representatives from government, house builders, a major developer, a major investor, the Housing Corporation, the Buildings Research Establishment (BRE) and the BioRegional Development Group (responsible for BedZED).

In parallel with the dialogue process outlined above, WWF held meetings with a wide range of stakeholders. These included representatives from government,[6] the house building industry, the investment community, and a range of other business interests. The feedback from the questionnaire and meetings represented an overwhelming consensus on the need for action.

As a result of this consultation, WWF identified six key barriers to development of sustainable homes. Our findings are summarized in the diagram on the following page.

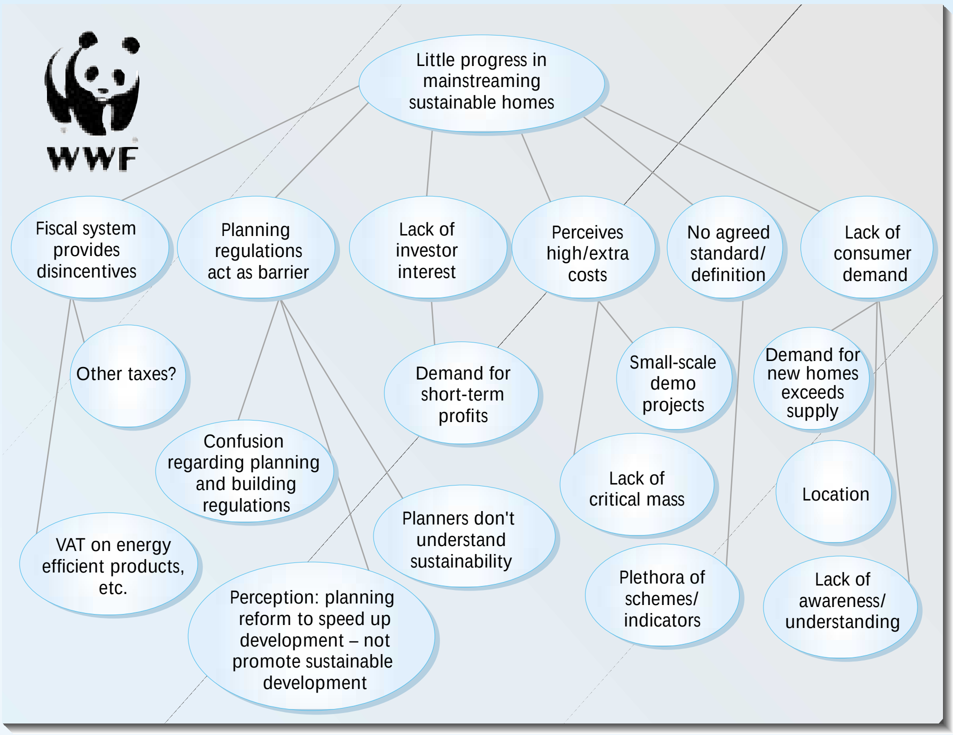
Stakeholders told us that barriers to sustainable homes include:

◆ current planning and building regulations that do not promote sustainable homes;

- ◆ lack of fiscal incentives;
- ◆ perceived lack of investor support;
- ◆ perceived extra cost;
- ◆ lack of consensus around the definition of a sustainable home;
- ◆ perceived lack of consumer demand.

One of the key barriers to progress in this area was the definition of a "sustainable home". We discovered a plethora of existing schemes and indicators, but little clarity regarding a definition. WWF found there was a general consensus that BRE's EcoHomes[7] standard was a good starting point, and BRE originally developed EcoHomes in consultation with an Advisory Group.

The feedback from stakeholders was that while EcoHomes is not perfect, it does begin to address the fundamental impact of housing on the environment. And BRE is committed to developing and improving the standard over time. The assessment covers areas of energy, transport, pollution, materials, water, ecology and land use, and health and well-being. WWF supports the EcoHomes "Very Good" and "Excellent" standards as a good measure of new and refurbished homes that have significantly less impact on the environment.



Next steps

WWF has secured commitments from a wide range of organizations, including house builders, developers and investors. We have now convened a "Sustainable Homes Task Force" comprising key partners from across a wide range of sectors responsible for overseeing the different strategies needed to overcome the barriers to sustainable homes.

These strategies include:

- ◆ ensuring that planning and building regulations facilitate the development of sustainable homes;
- ◆ ensuring that a range of fiscal incentives are introduced;
- ◆ demonstrating strong investor support for sustainable homes;
- ◆ ensuring that the cost of sustainable homes is competitive;
- ◆ developing the EcoHomes standard;
- ◆ building consumer awareness and demand for sustainable homes.

WWF believes government must show vision and demonstrate a lead in making sustainable homes the norm. WWF has recommended a number of tax incentives that could be introduced to encourage house builders and consumers to see the benefits of sustainable homes.[8] Government also needs to revise planning and building regulations to ensure that these critical forms of regulation support sustainable development rather than hinder it.

Government must lead by example as a construction client. It can do this by ensuring that all new homes for which it has responsibility meet at a minimum the EcoHomes "Very Good" standard. Finally, government should support communication of the social, economic and environmental benefits of sustainable homes to accelerate the step change that is needed in the way we design, develop and refurbish homes throughout the UK.

Conclusion

WWF does not support the "predict and provide" mentality for new developments, but it does accept that there is a housing shortage in the UK. Wherever possible, this should be met by refurbishing and renovating derelict and empty houses and other buildings, but where there is a real and justified need for new building, such developments should meet at a minimum BRE's EcoHomes "Very Good" standard.

One thing is clear: we only have one planet to live on, and this means that wherever new homes are genuinely needed they *must* be developed in a way that minimizes their impact on the global environment while optimizing social and economic benefits for occupants and the region.

Notes

1. WWF (2002) *Living Planet Report* (www.panda.org/downloads/general/LPR_2002. pdf).
2. Energy Saving Trust (2001) *Towards an Energy Efficiency Strategy for Households to 2020*. Supplementary Submission to the PIU Energy Review. October.
3. www.jrf.org.uk.
4. WWF (2002) Forests for Life. Working to protect, manage and restore the world's forests. August (www.panda.org/about_wwf/what-we-do/).
5. www.bedzed.org.uk.
6. Meetings were held with No. 10, DTLR & Millennium Communities, DEFRA, DTI, Scottish Executive, ACCPE (Advisory Committee on Consumer Products in the Environment), and Rethinking Construction (Housing Forum and Sir John Egan).
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Solar energy and eco-design in the tourism sector

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Accor hotel complex on the Olympic site in Homebush Bay, Australia

Accor is Europe's largest travel, tourism and corporate service group. It has 150,000 staff in 140 countries, There are nearly 4000 Accord hotels (443,000 rooms) in 90 countries.

Accor implements its environmental policy in hotel-building and renovation, notably by promoting solar energy. Within the Group, Accor also identifies and promotes innovative projects such as the Sydney Olympic Park Novotel and Ibis hotels, which have gone a step further in terms of improving environmental performance.

Solar energy in hotels

Since 1998 Accor has been involved in a programme to use solar water-heating technologies in its hotels. The Group has already undertaken several successful operations. In 1998 its Environment Department launched a programme with the Technical Department to study use of solar power to produce hot water for bathrooms. This project involved hotels in France, the French West Indies and Spain. By December of that year, the first installation had been set up at the Novotel Gosier Bas-du-Fort, which is equipped with 96 m^2 of solar panels. Today 14 installations have been completed, including eight in France.[1] The programme will continue both nationally and internationally.

As of March 2001, Accor was the company that had installed the greatest surface area of thermal solar panels in France (1300 m^2).

Eco-design and environmentally managed hotels

For the Olympic Games in Sydney, Accor opened a 327-room hotel complex in 1999 comprising Novotel and Ibis hotels at the Olympic site, Homebush Bay. In selecting the Accor project, Australian authorities were influenced by its full compliance with the environmental directives implemented by the International Olympic Committee. The consortium involved had committed consultants to prepare a strategy to maximize ecologically sustainable development principles and practices. This also involved drawing up environmental management plans for hotel design and construction and for ongoing hotel operation.

The hotels were designed with ambitious environmental objectives:

- *Building materials* were selected with specific requirements, e.g. low volatile organic compound paint, and flooring for the bar area and lobby staircase made of recycled graded hardwood.
- *Water saving* initiatives included grey water separation, treatment and reuse in toilets, irrigation, fire hydrants and the sprinkler tank, and collection of rainwater from the guttering in the garden watering storage tank for recycling.
- *Energy saving:* air conditioning automatically switches off in rooms if windows are opened; louvres are installed in the foyer for effective and natural airflow and energy saving; external awnings fitted to guest rooms reduce radiated heat from direct sunlight; all guest rooms have black curtains to block out light and absorb heat.
- *Renewable energy:* 250 m^2 of solar panels on rooftops produce 60% of hot water required for hotel bathrooms.
- *Waste recovery:* a worm farm deals with up to 150 kg of organic fruit and vegetable waste each week, producing fertilizer for the hotels' herb gardens.

To ensure full development of the potential of these eco-designed hotels, an environmental management system was implemented in 2000. While hotel environmental design and technical innovations are important, implementation and maintenance by staff of the environmental management system is critical to achieve significant environmental results. Environmental initiatives are integrated into operating procedures. Six months after opening, the Novotel and Hotel Ibis Sydney Olympic Park were the first hotels in Australia to obtain ISO 14001 certification.

These hotels use resources more efficiently, satisfying demand by an increasing number of clients who prefer to use businesses that reflect their own desire to care for the environment. Accor has also set up a partnership with the WWF through which one dollar is given to this organization for every room booked at the Novotel or Ibis Sydney Olympic Park.

Integrating environment in hotel management

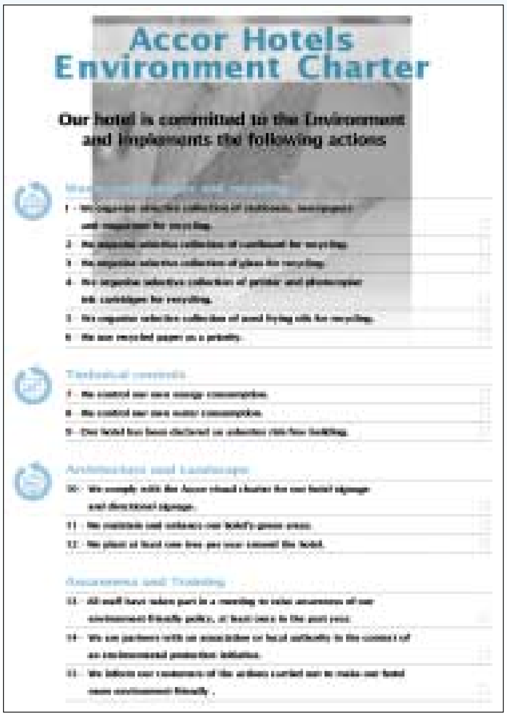
Integration of environmental criteria in hotel design is important, but it should be completed by environmental guidelines for hotel management. Most environmental impacts occur when hotels are exploited.

In 1998 Accor created the Hotels Environment Charter ("Charter 15") to integrate environmental management in hotels. The Charter gives each hotel the means to act locally in keeping with the specific aspects of the local business environment, while taking into account corporate guidelines. It has now been implemented in 2048 Accor hotels out of a total of 3711. The Hotels Environment Charter covers waste management and recycling, water and energy consumption, local involvement, employee training and awareness-raising.

Accor's administrative offices are also involved in waste management and recycling through separate collection of paper, batteries and printer ink cartridges for recycling.

The Charter 15 actions are presented in the Environment Guide for Hotel Managers, a training tool for hotel employees. Every year the progress of these initiatives is measured. The hotels report on their progress in implementing these actions. The results are published in Accor's Annual Report.

Since 1994 Accor has had an Environmental Manager, evolving in 1997 into the Environment Department. Support is provided by a network of 53 international representatives. These contacts reconcile the challenges of international and domestic environmental policies, help adapt these policies to the tourism sector and formulate an operational strategy for the Group.



Accor Hotels Environment Charter

Our hotel is committed to the Environment and implements the following actions

For more information, see: www.accor.com/gb/groupe/dev_durable/environnement/environnement.asp.

1.Novotel Gosier Bas-du-Fort, Guadeloupe, French West Indies (December 1998); Ibis and Novotel Homebush Bay, Australia (January 2000); Novotel Sophia Antipolis, France (June 2000); Formule 1 Perpignan, France (July 2000); Coralia Club Marina Viva Porticcio, Corsica, France (July 2000); Novotel Toulouse Aéroport, France (October 2000); Novotel Narbonne Sud, France (March 2001) ; Novotel Avignon Sud, France (April 2001); Sofitel Porticcio, Corsica, France (June 2001); Ibis Meknès, Morocco (September 2001); Ibis Castelldefels, Spain (December 2001); Hôtel Marissol, Guadeloupe, French West Indies (February 2002); Accor Academy, France (February 2002).

The role of policies in promoting sustainable practices

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Summary

Resource depletion is the most pressing overall concern related to the built environment. Determined policy development is needed to address this concern. Policies aimed at specific issues are not enough; a shift to "dematerialization" is required. Developing countries face particular barriers regarding policies on the built environment. In some countries of both the developed and developing worlds, promising steps are being taken, but to deal with consequences such as the rebound effect will require strong supranational efforts.

Resumé

L'épuisement des ressources est la principale source d'inquiétude en matière d'environnement bâti. Ce problème nécessite l'élaboration de politiques fermes. Mais les politiques axées sur des problèmes particuliers ne suffisent pas : une évolution vers la « dématérialisation » s'impose. Les politiques d'environnement bâti des pays en développement se heurtent à des barrières particulières. Si dans certains pays du monde développé et du monde en développement des mesures prometteuses sont actuellement prises, il faudra des efforts supranationaux énergiques pour faire face à des conséquences comme l'effet de rebond, par exemple.

Resumen

La disminución de recursos es la preocupación general más urgente relacionada con el medio ambiente construido. Es preciso elaborar políticas concretas que respondan a esta preocupación. Las políticas orientadas a cuestiones específicas no son suficientes: se requiere un cambio hacia la "dematerialización". Los países en desarrollo afrontan barreras particulares respecto de las políticas sobre el medio ambiente construido. En algunos países, tanto desarrollados como en desarrollo, se están tomando medidas prometedoras, pero para hacer frente a las consecuencias, como el efecto de rebote, se necesitarán acciones sólidas a nivel supranacional.

Policies have a key role in supporting moves towards sustainable building and construction (SBC). The sustainability of the built environment, in turn, is a key element in efforts to halt the spiral of resource depletion that jeopardizes the future of our planet. The current political climate tends to favour market-based initiatives to promote sustainability. However, recent studies show that, as far as SBC is concerned, the optimum solution is a combination of market-steering measures and integrated policies, efficiently implemented and enforced. Yet the development of effective policies is not easy.

Furthermore, even the most successful of existing policies geared towards SBC are barely making headway even against basic environmental problems related to the built environment, never mind addressing the urgent issue of reducing resource use by a factor of four or more in order to establish a balanced resource system. A sea change is needed: policy development even in the most progressive countries is not yet grounded in the principles of sustainability.

Current issues

The limits of the planet's resources and the threat of climate change translate into a need to minimize use of materials and of fossil fuels. These are the first concerns that SBC tried to address, and they remain the most important ones.

Other issues, such as indoor air quality, green spaces, health issues, traffic patterns and social issues, have come to be included in various cultures' understanding of the term. But the world is not getting any nearer to sustainability, even with respect to SBC's two original concerns. In the case of each of these issues a new, innovative policy strategy is needed.

The results of a four-year OECD project confirm the importance of policies in promoting SBC. The synthesis report of this project defines four criteria for evaluating policy instruments:[1]

- environmental efficiency (how much the instrument contributes to achieving the policy objective, e.g. reducing environmental loading);
- economic efficiency (the extent to which the instrument enables least-cost achievement of an objective);
- incentives for innovation (how much the instrument stimulates innovation and the diffusion of cost-effective technology);
- administrative costs (whether they are within acceptable limits, for both public authorities and private companies).

Thus far, few policies or policy instruments aimed at the building and construction sector have stimulated progress beyond the level achieved by building regulations. Energy and environmental audits appear to have encouraged the introduction of measures. Tax benefits look as if they might be a promising financial driver, as some countries have demonstrated. But in general there is an urgent need for innovation, ideas and further development of policies to promote SBC.

Policy results

The OECD review includes a number of policies that have been successful, though these policies do not go far enough. One is the Dutch policy aimed at diverting construction and demolition waste from landfills via waste reduction and recycling. It has resulted in over 90% of such waste now being recycled or reused, owing to a combination of environmental regulations, taxes, and (later) a ban on dumping.

The success of this policy does not mean the Netherlands has solved the problem of resource management. It has yet to make the shift to a closed-cycle, sustainable resource management policy whose emphasis would be on reducing the amount of material consumed to begin with.

Japan appears to be on the road to such a shift. The 2000 Basic Law for Establishing a Recycling-Based Society provides some good starting points for moves towards "dematerialization". The structure of its approach to resource management is probably the best in the field. However, targets were not set and results so far have been marginal. It has been reported that awareness of the need for regulation is growing in Japan.

Studies show that most European countries' policies have brought only slight progress so far.[2] For measures to have a real impact, legislation needs to be accompanied by targets and regulations.

Despite examples of policies in some countries that have had interesting results, these are a long way from being enough.

In a study comparing SBC-related policy in Finland, the Netherlands, France, Germany and the UK, Minna Sunikka concludes that despite government support in areas such as information dissemination, progress towards sustainability in the construction sector appears to be very slow. Information on sustainability, a long-term outlook and a clear definition of the concept are often lacking in the sector, the study found.[3]

Even if all current policies and plans on SBC in these five countries were being fully implemented, this report maintains that their national strategies are not ambitious enough to bring about true sustainable development, as defined and agreed at the Rio Earth Summit of 1992.

Developing countries

If strong policies can help industrialized countries lead society towards sustainability, such efforts in developing countries face particular barriers. For example, small and medium-sized construction companies in most Sub-Saharan countries are generally not registered with the tax authorities and do not pay taxes. It would be next to impossible to apply fiscal measures to them.

In many countries lack of planning or (in fast-growing countries) inability to keep up with the speed of growth is one of the most pressing problems at regional and municipal level. Most developing countries have a large informal building and settlement culture. Where attention is paid to any sustainability aspects at all, these usually involve air pollution, dust, wastewater, waste and traffic rather than building-related problems – though of course construction and buildings contribute to all these problems.

Awareness of resource management issues is generally scant to non-existent. Indeed, where resources are concerned, attitudes in much of the developing world are characterized by a desire to use what are perceived as "noble" materials (e.g. aluminium, steel, concrete) and by the belief that "Western" equals "modern", as well as that achieving progress inevitably entails increased energy use.

In developing countries where traditional, often more sustainable construction materials and methods persist, it is rapidly becoming difficult to take advantage of them owing to the rate at which local building material industries are disappearing. People and industries act within the boundaries set by policy and economics, which in much of the world do not favour sustainable options. Some political awareness of such options exists here and there, but development of this awareness is often impeded by unpredictable political situations and/or corruption at many levels, with officials unlikely to be interested in better legislation.

On the positive side, the cultures of many developing countries still preserve their traditional ways if only in people's memories. Where their cultural values stress balanced use of natural resources, such countries may have a head start towards adoption of sustainable approaches. It is essential to include this element in new policies and approaches, just as it is essential to find ways to include the informal sector. In each case this is conditional on getting government officials and political leaders involved. Furthermore, involvement is not enough. As a major sustainability analysis of urban settlements in South Africa concludes: "Settlements will only be sustainable once the values of sustainability have become the basis from which the majority of decisions on the creation and management of settlements are made."[4] Of course this conclusion applies equally to developed countries.

At a Dutch company specializing in recovery of old building materials for reuse, nails are removed from planks, which are checked in a metal scanner (foreground) and remilled

Making sustainability central

Policies to date have focused mostly on single issues such as energy efficiency. However, sustainability needs to be the main driver of policy development, not just one of the parameters. As an important indicator of a shift to sustainability (in general development terms, and in the SBC sector in particular) we might consider whether a country has anchored sustainable development in its overall policies and even in its legislation or constitution.

A few interesting examples exist. Take the kingdom of Bhutan, a small country north of India, whose monarch has defined progress not as gross national product but as "gross national happiness". Bhutan's official policy is that any type of development should be judged according to whether it contributes to this type of progress – a difficult task, but a beautiful concept. Another example is the Constitution of East Timor, which became independent from Indonesia in May 2002. In founding the new country and writing its constitution, East Timor's leaders have made sustainable development a basic right and duty of the state and its citizens. More recently, France has begun the process of amending its constitution to require the state to promote sustainable development and apply the precautionary principle.

An example more specific to the building and construction sector is the definition of public housing in Swedish law: "Housing is a social right, and the aim of housing policy is to create conditions that enable everyone to live in a good home at a reasonable cost in a stimulating and secure environment, within ecologically sustainable limits. The housing environment should contribute to equal and decent living conditions and should, in particular, promote good conditions for children and young people to grow up in." A project in which these principles are being carried out is the City of Tomorrow in Malmö where, among other goals, 100% of energy is to be provided by renewables (see photo on following page).

While many countries in Europe have not reached this stage yet, the European Council has taken a major step towards doing it for them. In the communication issued following the Council's Gothenburg summit in 2001, European leaders strongly endorsed sustainable development. They declared, among other things, that "[the] relationship between economic growth, consumption of natural resources and the generation of waste must change. Strong economic performance must go hand in hand with sustainable use of natural resources and levels of waste, maintaining biodiversity, preserving ecosystems and avoiding desertification."

As a consequence of this statement, the European Commission is working on a resource strategy that is expected to go far beyond the current focus in most countries, especially as regards recycling (see http://europa.eu.int/comm/environment/natres/index.htm). An example of concrete progress in the EU is the Energy Performance of Buildings Directive, whose key provisions include minimum energy performance requirements for all new buildings and for existing large buildings undergoing major renovation; energy certification for all buildings (frequently visited buildings where public services are provided will have to display the energy certificate prominently); and regular mandatory inspection of boilers and air conditioning systems.

Barriers and challenges

One of the main barriers to SBC is that the building and construction sector is not recognized as a responsibility to be shared by different countries. At EU level, for example, there is no mandate to develop common policies on construction or housing. The Plan of Implementation adopted at the 2002 Earth Summit in Johannesburg does commit governments to"[use] low-cost and sustainable materials and appropriate technologies for the construction of adequate and secure housing for the poor, with financial and technological assistance to developing countries, taking into account their culture, climate, specific social conditions and vulnerability to natural disasters." However, this clause is aimed principally at poverty alleviation rather than SBC.

Documents from the Earth Summit emphasize

In the City of Tomorrow (Malmö, Sweden) 120 m^2 of photovoltaic cells help supply energy needs

the duty of the private sector to "contribute to the evolution of equitable and sustainable communities and societies". They mention the need for: provision/improvement of rural infrastructure and sanitation; improved access to property, shelter and services for the poor; reduced energy use; integrated policy making and material reuse; and other topics related to this sector. But there is nothing specifically about balanced resource management.

A further challenge is the risk that policies for SBC will be offset by rebound effects. For example, a successful campaign for use of energy efficient light bulbs may not produce any energy savings if users install more lights or leave lights on longer. Similarly, it has been shown that many of the benefits of applying SBC principles in a new residential area are lost if the development is located so far from jobs and services that extra energy for commuting is required.

Rebound effects can be seen in material use. Charles Kibert has reported that in the past 30 years the average area of a US living unit has grown from 170 to 220 m^2 while average occupancy has fallen from 3.5 to 2.5 people. In most industrialized countries, he notes, "aggregate materials use or throughput ... is steadily increasing and environmental damage is climbing proportionately."[5]

The building and construction sector also has its own barriers, such as the fact that longevity of buildings makes the economic benefits resulting from energy efficiency investment uncertain. Moreover, where there are both owners and users, "principal agent" problems occur with respect to improving energy efficiency in buildings.

There is no one agreed method for assessing the environmental impact of energy, water and material use. National policies concerning building and construction differ considerably, and knowledge of these impacts is limited. Nor is there a broadly accepted terminology for issues related to recycling of waste materials and products. The construction industry has to deal with legislation that varies according to country and is based on differing information and data. Countries are developing their own tools to assess the same products in different ways. Construction materials and products are the building sector's main asset in free trade and cross-border activities. To harmonize the various national approaches will require, once again, strong international cooperation.

Countries in transition face special problems in this connection, especially those that will join the European Union. They will have to adopt EU standards for building and construction, a move that will mean significant progress in many areas. But these standards are not yet in place for all aspects of SBC, and they are not sufficiently stringent in some areas. The building and construction sector in the accession countries will need to adapt to EU legislation even as they learn to cope with open borders and free trade.

EU membership will mean that many local companies in the sector will disappear. Local building products will be replaced by Western imports. This will make it extremely difficult to establish a strong local-based climate for SBC. From a sustainability point of view, it would be better if most of these countries could take a few years to build a strong local industry that could cope with EU legislation and better compete with imported products and foreign-based companies.

Solutions involve major shifts

If we are beginning to understand the barriers and arrive at the solutions involved in establishing a society driven by SBC, or by recycling and renewable forms of energy, putting the solutions into effect is another matter. As Gary Gardner and Payal Sampat have written, "Given the record of [the last] century, an extraterrestrial observer might conclude that conversion of raw materials to wastes – often toxic ones – is the real purpose of human economic activity."[5]

Our resources are limited. If we do not make a shift, nature will do it for us. To bring about a shift in resource management will require reinvention of the now predominant economic system and the policy making that guides it. This system is very complex, and considerable insight into its workings will be necessary if we are to avoid unexpected consequences such as major rebound effects.

For a start, old-fashioned subsidies to industry, mining, transport and new building need to be replaced with measures to support closed cycles for all materials and products. The building and construction sector could be at the forefront of this change. Its products have a longer lifetime than average products, and with appropriate renovation and maintenance they can be made useful virtually forever. In this sector a zero-materials strategy, developed in line with a zero-energy strategy, could well be in reach.

Recent research and models provide some clues about how to go about this. First must come a shift in the focus of policies from new structures to existing ones, aiming for repeated reuse. Only now are we starting to realize that the real advances can be made in the existing building stock, which in many countries amounts to up to 99% of total stock, with only 1-1.5% added or replaced each year.[7]

Another key shift will mean restructuring policies to favour services over products. Current discussions of effective policy involve extending producer responsibility to the whole lifetime of a product. In the buildings sector this can be translated as "servicing shelter". Solar cells in roofs provide an example of such "product service systems": in some projects the roof (as a surface) is leased to an energy supply company. The company takes full responsibility for the roof, both as a watertight surface and as a source of profit via the green electricity produced by the solar cells. This avoids the guarantee problems that could arise if two companies were involved in maintaining the roof.

Of course SBC is not only about environmental concerns. In addition to securing our physical resources, SBC means paying attention to social and cultural values. The importance of these aspects is only recently being recognized in the sector. The main elements receiving attention are the history and traditional values of people in different cultures and climates, which have often been overlooked in modern building and planning. As a World Bank report on a Chinese development project puts it, "[The] loss of urban neighborhoods and historic sites was once thought to be the price of progress. However, planners now recognize that preserving the past is an essential part of creating livable, sustainable cities."[8]

The city of Riyadh in Saudi Arabia provides another example of attention to social and cultural factors. Certain local planners realized that copying western building styles was not very efficient in their climate, nor did it correspond to people's cultural needs and habits. In a new developed area they decided to use the traditional local approach. They designed a combined commercial-residential area in the medina style, using mud-brick construction, the traditional building method which has many advantages in terms of comfort as well as resource use.

Such examples illustrate that social and cultural aspects can relate very closely to environmental ones, and can even be mutually reinforcing with use of local resources, attention to the existing building stock and respect for cultural values. Policies that follow such an approach can help improve environmental conditions while meeting people's wishes and needs.

In short, in a very real sense SBC is all about policies and how we organize our society and our markets. The need for a global approach is clear if we look at the Pacific island nations, for example: it is not the lack or failure of local policies that threatens these islands, but sea level rise resulting from climate change reflecting policies in the developed world. It is not enough for industrialized countries to work to develop sustainability within their own vigorous economic system. The survival of many other countries depends on policy makers' paying serious consideration to situations in the developing world.

Further research on existing policies could help reveal the most successful approaches for sustainability. A necessary first step is to inventory policies in many countries related to building and construction. The Sustainable Building Support Centre at the Institute for Housing and Urban Development Studies (IHS) in Rotterdam began such an inventory in January 2003, in line with a recommendation from the IEA, the OECD and EU housing ministers. So far, 11 countries have signed up and are assembling policy information to be processed and made easily available through the Sustainable Building Information System being developed by the International Initiative for the Sustainable Built Environment (iiSBE). It is expected that an initial overview and analysis of trends will be published by the end of 2003.

Conclusions

Policies are essential to achieve SBC and balanced resource management. Existing policies have not led to any real shift. For example, most countries will probably not be able to meet their Kyoto Protocol targets despite climate change policies. A large part of the problem is not the lack of sustainable building policies, but rather the need for awareness on the part of political leaders. Policies should focus first and foremost on the existing building stock.

Notes

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Do standards and regulations supply the necessary incentive for sustainable building?

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Summary

Various environmental policies' approach to sustainable development can serve as a baseline for assessing how well regulations and standards will promote sustainable building and construction. If followed up, existing acts, regulations and standards generally lead the industry in the right direction. Achieving sustainable buildings, however, will require additional action at the policy level. This article looks at acts, regulations and standards concerned with sustainable buildings nationally and internationally, including International Organization for Standardization standards currently under development. International standards and regulations do not yet address the problems of the developing world satisfactorily, though this issue is receiving growing attention.

Résumé

Diverses stratégies environnementales du développement durable peuvent servir de base pour déterminer dans quelle mesure la réglementation et les normes sont susceptibles de promouvoir une industrie de la construction durable. A condition d'en contrôler l'application, les lois, réglementations et normes existantes entraînent généralement l'industrie dans la bonne direction. Mais construire des bâtiments durables exige également une action sur le plan politique. L'article fait le point sur les lois, réglementations et normes nationales et internationales relatives au développement durable du bâti, notamment les normes de l'Organisation internationale de normalisation (ISO) actuellement en cours d'élaboration. Mais les normes et la réglementation internationales n'apportent pas de solutions satisfaisantes aux problèmes du monde en développement, même si cette question retient de plus en plus l'attention.

Resumen

El planteamiento del desarrollo sostenible en las políticas ambientales puede servir como base para evaluar en qué medida las reglamentaciones y normas fomentarán las edificaciones y la construcción sostenibles. De aplicarlas, las leyes, reglamentaciones y normas existentes generalmente indicarán a la industria el camino correcto. Lograr edificaciones sostenibles, sin embargo, requerirá acciones adicionales a nivel de políticas. En el artículo se analizan leyes, reglamentaciones y normas relacionadas con edificaciones sostenibles a nivel nacional e internacional, entre otras, las normas que se están preparando en la Organización Internacional de Normalización (ISO). Las normas y reglamentaciones internacionales todavía no tratan satisfactoriamente los problemas del mundo en desarrollo, aunque actualmente se presta más atención a este problema.

The meaning of the term "sustainable development" is disputed and complex. The most frequently quoted definition is that of the World Commission on Environment and Development (1987): "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." There are few specific agreed sustainable development strategies.

The International Organization for Standardization's definition of sustainability is "the maintenance of ecosystem components and functions for future generations" (ISO, 2002a). The ISO standard in which the general principles of sustainable building are set out applies this definition and identifies the following elements:

Environmental. Design, construction and operation must implement DfE (design for environment) approaches. The healthy functioning of local, regional and global ecosystems must be promoted, and energy efficiency, toxicity, materials, durability, reuse and building operations must be incorporated.

Social. Buildings, individually and collectively, influence many aspects of human behaviour (including daily travel patterns) with their own substantial social costs and environmental costs. Design, construction and operation must incorporate collaboration, social impacts and continual improvement.

Economic. Sustainable building must incorporate full-cost accounting procedures into the development of buildings and constructed assets. It must address not only initial direct economic costs of development, but also associated direct and indirect social and environmental costs.

ISO standards under development in the sustainable building area

Within the International Organization for Standardization's Committee on Sustainability in Building Construction (ISO/TC59/SC17), current standardization activity in the area of sustainable building and construction assets involves:

- Building and constructed assets – Sustainable building – General Principles;
- Building and constructed assets – Sustainability – Sustainability Indicators;
- Building and constructed assets – Sustainability in building construction – Framework for assessment of environmental performance of buildings;
- Building and constructed assets – Sustainability in building construction – Environmental declaration of building products;
- Building and constructed assets – Sustainability in building construction – Terminology.

These standards constitute a hierarchy (Figure 1).

In the proposed General Principles standard (ISO, 2002a) it is stated that this standard does not represent a benchmark against which a claim of sustainability can be made. Rather, it is a description of the general principles of sustainability whose purpose is to identify the relationship of these principles to the building industry and to establish a rationale for subsequent related standards. Some of these standards are described below.

Sustainability indicators

The aim of the standard on Sustainability Indicators (ISO, 2002b) is to define a framework with respect to sustainability indicators for buildings and groups of buildings. In this standard it is stated that the general understanding of the aspects of sustainability – including economic, environmental and social ones – is adopted. However, environmental and social costs seem to be missing. At least there are no defined indicators for these costs in the current version of this standard. The following core set of indicators is recommended:

- use of natural raw materials;
- consumption of energy resources;
- release of environmentally harmful emissions;
- access (by public transport and bicycle or pedestrian traffic);
- service life;
- indoor conditions;

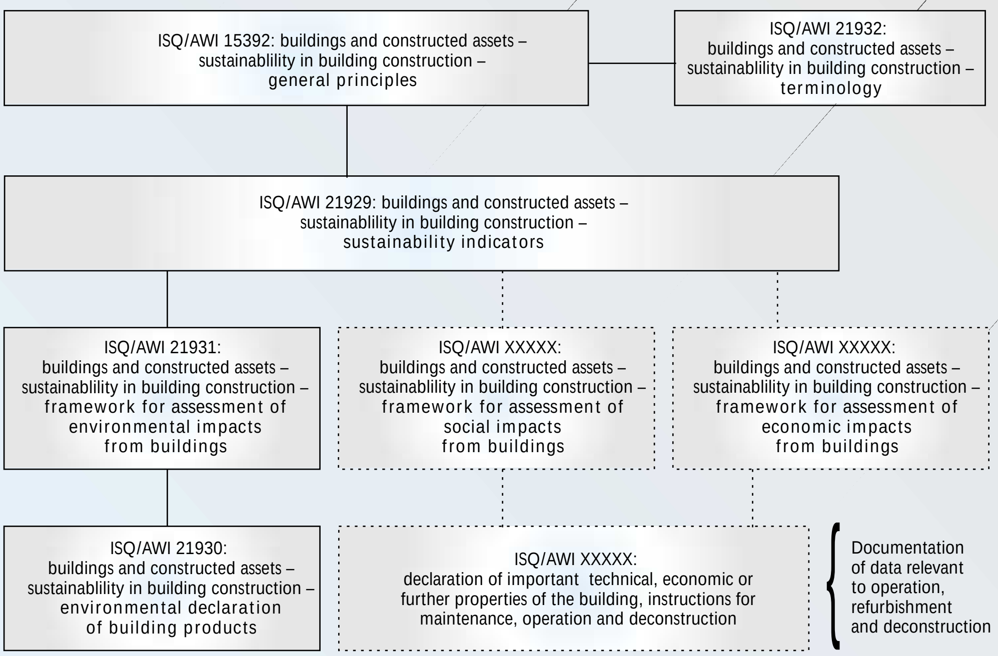


Figure 1
Standards under development, and planned standardization in the area of sustainable building (ISO, 2002a)

- barrier-free use by the handicapped;
- costs over entire life.

Indicators of sustainable development and sustainability indicators are developed at several levels. The Worldwatch Institute, for example, is responsible for the “State of the World” indicator set, which is used to monitor data trends affecting the environmental health of the planet (e.g. fertilizer use, carbon emissions), the state of the economy (e.g. developing countries’ foreign debt, world trade in food and agricultural products), and health and social conditions (e.g. HIV/AIDS, cigarette smoking).

Various indicators have been developed for national and local use, but with a strong tendency to include only environmental aspects. The UK government has developed a set of 120 indicators for sustainable development. The UK’s approach to sustainable development is to ensure better quality of life for everyone, now and in generations to come. This statement is followed by the definition of four key objectives that must be met for the UK and for the world:

- social progress, which recognizes the needs of everyone;
- effective protection of the environment;
- prudent use of natural resources;
- maintenance of high and stable levels of economic growth and employment.

The difference between the UK strategy and other strategies is the strong focus on economic growth and the standard of living. Its indicator system includes indicators for social aspects (e.g. poverty and social exclusion, education) and economic aspects (e.g. GDP, social and total investments, employment). It is therefore closer to the sustainability concept than are other systems. However, an indicator on this level must be used at the level of a single building or group of buildings.

CRISP is a European Thematic Network whose main objective is to create a group dynamic in the field of construction and city related sustainability indicators. Its purpose has been to coordinate current research concerned with defining and validating indicators and implementing them, in order to measure the sustainability of construction.

Framework for assessing the environmental impacts of buildings

Work on the standardization of frameworks for assessing buildings’ environmental performance includes a description of principles and a framework for environmental assessment of new and existing buildings, considering various environmental impacts and burdens associated with design, construction, operation, refurbishment and deconstruction (ISO, 2002c). The basis is the development of various building assessment methods and the need to improve these methods’ quality and comparability.

As seen in Figure 1, which illustrates the relationship between the different standards, an assessment of environmental impacts does not claim to be an assessment of a building’s sustainability since only the environmental aspect of the sustainability concept is included. This is also the case for most existing building assessment systems. Many of them present only a good resource and environmental profile of the building in operation.

The Norwegian Ecoprofile of a building is divided into the three performance areas of “external environment”, “resources” and “indoor climate”. These areas are then divided into categories with different consequences for the performance areas. Each category contains a number of criteria and sub-criteria that are individually evaluated and given a grade. Figure 2 shows the structure of Ecoprofile for office buildings. For other types of buildings there are some changes in categories, weighting, and parameters.

Environmental declarations

Environmental declarations aim to provide information (based on LCA, or life-cycle assessment) for manufacturers and consumers of building products enabling them to make decisions that will minimize the negative environmental impacts of building and construction work. There are several national initiatives in this area. The standard on environmental declarations of building products (ISO, 2000d) is intended to harmonize different approaches as far as possible.

In the environmental declaration of a product, the functional unit is given for the product’s principle function over the entire life of the building (“from cradle to grave”).[1] This implies that maintenance, replacement, etc. are to be included in the functional unit. The lifetime of a building in the Norwegian and UK systems is set at 60 years. The functional unit is therefore to be given for a corresponding period. Environmental declarations are regarded as part of a building’s environmental assessment, and as only one of many elements of the sustainability concept.

Acts and regulations in this area

In many countries environmental requirements are included, to some extent, in building related acts and regulations. The most comprehensive requirements are found in technical regulations under the planning and building act and the regulation concerning requirements of buildings and products for buildings. It may be stated that building activity in all its phases (i.e. acquisition, use and demolition) should be carried out with a justifiable load on resources and the environment, and without deterioration of quality of life and living conditions. However, these requirements are not followed up in related regulations such as those concerning public enquiry and control.

Local governments responsible for following up on violations of regulations lack knowledge and tools in this area. To state that a building does not satisfy the environmental requirements of the regulations is entirely different from stating that a roof is inadequate considering the area’s snow load.

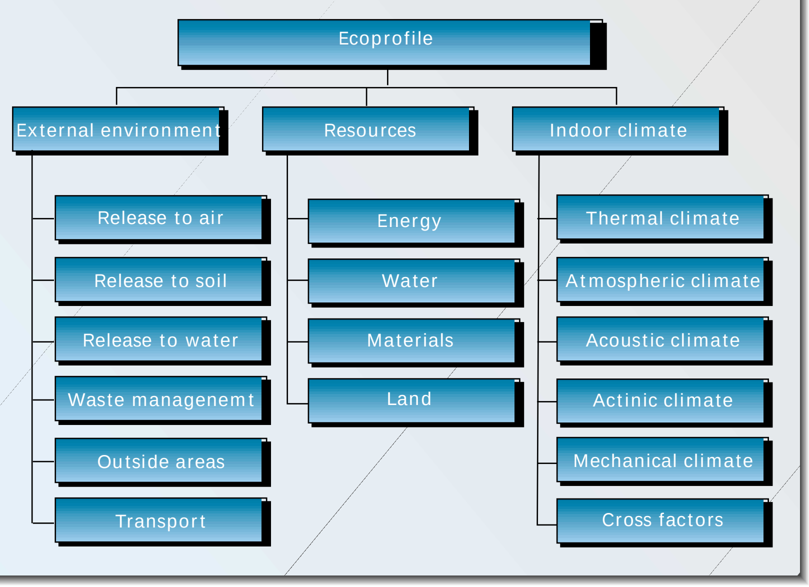
Suitability in developing countries

Developing countries, with their rapid development and large populations, are very important in the context of sustainable development. *Agenda*

21 for Sustainable Construction in Developing Countries describes the situation in these countries and discusses a strategy for action to reach sustainable development (CIB and UNEP-ITEC, 2002).

The main issue is that developing countries struggle with different problems than those of developed ones. While there are similarities, developing countries face greater differences and more extreme problems with fewer resources to deal with them. Critical issues are access to adequate housing and infrastructure, rapid urbanization, informal settlements, and lack of institutional capacity. Two factors in particular represent the difference between developed and developing countries: a significant portion of houses in the latter are built by family members (45-50% in Bolivia), and small local companies produce a very important proportion of building materials (often involving high emission rates).

Figure 2
Structure for the three principal components of the Norwegian Ecoprofile and their sub-components



Two main strategies have been identified concerning which way to go:

- follow the Western "model"; or
- establish a different vision of development, including non-Western values.

The principal barriers to sustainable building in developing countries are described, among other places, in the working document of *Agenda 21 for Sustainable Construction in Developing Countries*. They include:

- lack of capacity in both the construction sector and governments;
- lack of effective power in (governmental) environmental institutions;
- financing and uncertain economic environment;
- poverty and the subsequent low urban investment and ability to pay for services;
- lack of interest in the sustainability issue by stakeholders;
- technological inertia and dependency due to entrenched colonial codes and standards;
- general lack of data, standardization and codes to support, for example, the establishment of national benchmarks;
- a low level of environmental concern among citizens;
- lack of institutions to facilitate appropriate policies.

How to overcome these barriers cannot be described in detail in this article, but some important actions are suggested. Solutions need to be sought in many areas, including education, finance, policies, development of tools and benchmarks, development of standards, codes and regulations, and research.

Education is perhaps the most important. It entails educating professionals at different levels. One task is in-service training, which could be carried out following the Sri Lankan model for educating processionals about cleaner production. In Sri Lanka's Industrial Pollution Reduction Programme (IPRP) two groups were trained in cleaner production assessment. The professionals who received this training were chosen from a wide spectrum representing industry, academic institutions, development banks, private consultants, research institutions, etc. which performed functions in different parts of the production industry. Sustainable development also needs to be integrated into the education of architects, planners and engineers. Together they would form a body of sustainable design implementers.

It is important to establish national financing mechanisms for the transfer of sustainable technology. Development and implementation of sustainability also depends on an active research community. Research is necessary for developing and adapting new technology, standards, codes and regulations, tools and methods, to provide data and establish benchmarks.

Few developing countries have their own tools for use in sustainable building. The South African "Sustainable Building Assessment Tool" (SBAT) supports implementation of more sustainable practices in the building and construction industry in developing countries, particularly in South Africa. SBAT includes environmental, economic and social aspects; it aims at assessing not only a building's sustainability, but also the extent of its contribution to the support and development of more sustainable systems around it. The Green Building Assessment Tool (GBTool), which has been used in countries including Brazil and Chile, needs to be simplified and adapted to developing countries. Problems in developing an assessment tool are lack of energy codes or national standards on whole building performance, lack of climatic data, outdated existing standards, and lack of LCA data. There is a general lack of data in standardizations to support establishing national benchmarks.

Another difficulty in reaching sustainable development is how to modify people's daily activities. Collective effort is needed, and this might be regarded as the strength of developing countries. Norway's "Environmental Home Guard" (EHG) takes the task in hand. This NGO is a network of individuals, groups, organizations and institutions committed to changing their daily activities in ways that reduce use of natural resources, energy and environmentally harmful substances, minimize waste generation and protect biodiversity. They provide information, produce tools, recruit people for networks and help voluntary organizations, institutions, schools, etc. to improve their environmental profiles.[2]

In implementing sustainability, the main players are the government and authorities, educational institutions and the research community. Involvement by the government and authorities is crucial and must include both policy and financial support. In addition, institutions need to have the power to enforce necessary changes. In many developing countries this would be a good place to start. In European countries where there is strong support by authorities, the success story has been different from the situation in countries without this support. The Netherlands and Denmark are leaders in the area of sustainable building in Europe.

The need to go beyond existing acts, regulations and standards to reach sustainability

The standards and regulations described above do not adequately address the problems of the developing world. In *Agenda 21 for Sustainable Construction in Developing Countries* it is argued that planning acts, building codes and regulations adopted from the West often discourage or even forbid housing development based on traditional concepts, which often provide the most sustainable solutions. Building codes and planning concepts from the colonial period have been seen as superior to anything found in the colonies. This has created a general lack of confidence in homegrown solutions and traditions, which are actively discouraged. In addition, earth construction techniques came into disfavour mainly due to the technological changes brought by the Industrial Revolution and consequent demand from the consumer market.

A very important point also mentioned in the Agenda 21 report is the possibility for developing countries to offer sustainable development opportunities that are not common in the developed world. Through their cultural heritage, innovative local solutions and adaptability, developing countries might have one of the keys to sustainability.

In the developed world solutions are traditionally sought in new technology, while in developing countries tradition represents a more people-centred development. This last view is consistent with the belief that people's behaviour and choices will determine the success or failure of sustainable development and construction, not just the availability of sustainable technology.

Existing acts and regulations from the West are not necessarily suited to the developing world. Nevertheless, knowledge transfer is necessary to reach sustainable development in these regions. It might also be appropriate to ask whether modern buildings can be sustainable at all, as construction of a building always entails a load on natural resources and the environment. However, housing is necessary and provides economic and social benefits. By including these factors and substantially reducing the environmental load, sustainable building should be possible. Perhaps the construction industry is moving in the wrong direction – increasing the load on nature, often disregarding social aspects, and only including economic considerations in terms of the private investment economy. Sustainability will involve a total paradigm shift that the building industry is far from realizing.

Whether the revised standards, acts and regulations relevant to sustainable construction in this article can be interpreted as sustainable may be doubted. The General Principles standard provides a starting point, including a description of sustainability and the link to the building industry. The next step is the Indicator standard, which aims to define indicators for buildings or groups of buildings. Comparing the core set of indicators with the ISO definition of sustainable building, it can be seen that they only address some aspects; socio-economic aspects in particular receive minimal attention. Standards on the next level of the hierarchy cover only environmental aspects, and thus only one of the three aspects of sustainable development. The methods used to assess a building's environmental quality should be extended to include economic and social aspects. However, barriers in technology or demand and willingness to pay for improved buildings may not be eliminated through standardization.

At best, acts, regulations and standards represent what might belong in a vision of weak sustainability. They are a reflection of where we stand today technologically, and the degree to which the industry has realized the need for change. For example, zero energy dwellings are possible but are not required by today's regulations. This is because it is inadvisable to move too fast, as economics in the industry limits the room for action (economics is also is an element of sustainable development). Again, as industry struggles to meet new requirements, it is inadvisable to move too fast for economic reasons. However, standards may involve freedom to include drastic sustainability concepts. Acts, regulations and standards need to be under constant development and to implement new knowledge as it evolves.

An element missing in regulations today is maintenance and management (MM). MM is a very important part of sustainability, as it entails maintaining the benefit created through buildings for future generations. The standard on sustainability indicators could be used to start this process. However, a set of indicators also needs a method for monitoring the indicator and assessing the status of a building.

Conclusion

Existing acts, regulations and standards lead the industry in the right direction if they are followed up. However, to reach what can be called sustainable buildings requires additional action on the policy level. This should involve providing incentives and disincentives (e.g. through taxes) and funding and support for innovative businesses and technology. Special funding for good examples of sustainable buildings is still necessary. Some sources maintain that the "the time of the pilot project is surpassed, and that it is time to implement the knowledge in mainstream building". However, this is not the case. It is correct that what has been seen in pilots up to now should be included in mainstream building, but there is still a long way to go. As we are very far from the goal, pilot buildings are still useful for testing new technology and solutions. Finally, education is crucial when implementing change. The understanding of sustainable development and the changes this involves for industry must be included in all professional studies within building and construction. It can be expected that the type of changes needed will take at least one generation.

Notes

1. For more on the use of functional units to make comparisons on a like-for-like basis, see "Construction products and life-cycle thinking" by Suzy Edwards and Philip Bennett on p. 57 of this issue.

2. See "Norway's Environmental Home Guard" by Terje Torkildsen, *Industry and Environment*, Vol. 25, No. 3-4, July-December 2002, pp. 86-87.

References

CIB (International Council for Research and Innovation in Building Construction) and UNEP-ITEC (United Nations Environment Programme – International Environmental Technology Centre) (2002) *Agenda 21 for Sustainable Construction in Developing Countries. A discussion document*. Boutek Report No. Bou/E0204. Published by CSIR Building and Construction Technology, Pretoria, South Africa (www.csir.co.za).

International Organization for Standardization, standards under development:

- ISO (2002a) *ISO/TC 59/SC 3 N 459, Building and constructed assets – Sustainable building – General principles.*
- ISO (2002b) *ISO/TC 59/SC 3 N 469, Building and constructed assets – Sustainability – Sustainable indicators.*
- ISO (2002c) *ISO/TC 59/SC 3 N 467, Building and constructed assets – Sustainability in building construction – Framework for assessment of environmental performance of buildings.*
- ISO (2002d) *ISO/TC 59/SC 3 N 467, Building and constructed assets – Sustainability in building construction – Environmental declarations of building products.*

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Life-cycle costing in the construction sector

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Summary

The construction sector is a major consumer of natural resources. Inability to predict performance reliably can result in unsustainable waste (through over-design) or costly premature deterioration. Life-cycle costing makes it possible for the whole life performance of buildings and other structures to be optimized. Its value is highlighted by the increasing use of private finance initiative type procurement, in which a developer/builder operates and maintains the structure over an agreed period. This article introduces the concept of life-cycle costing as used in the construction sector. It briefly explains how LCC is carried out and some of the barriers to its adoption. Initiatives seeking to tackle these barriers are presented. A case study illustrates payback on investment to reduce energy consumption. For this exercise, two design options were developed: the original client-compliant design and an energy efficient option.

Résumé

Le secteur du bâtiment est un gros consommateur de ressources naturelles. L'incapacité de prévoir avec justesse les performances des constructions peut se traduire par des volumes de déchets contraires au concept même de développement durable (design trop recherché) ou par une détérioration prématurée coûteuse. L'évaluation du coût du cycle de vie permet d'optimiser les performances des bâtiments et autres constructions pendant toute leur durée de vie. L'intérêt de cette évaluation a été démontré par le recours de plus en plus fréquent à des projets menés par financement privé dans lesquels le promoteur ou le maître d'œuvre exploite et entretient la construction pendant une durée déterminée. L'article présente le concept d'évaluation du coût du cycle de vie tel qu'il est appliqué dans le secteur du bâtiment. Il explique comment est effectuée l'évaluation et quels obstacles freinent son adoption ; il présente quelques initiatives visant à lever ces barrières. Une étude de cas illustre le retour sur investissement des efforts de réduction de la consommation d'énergie. Deux options architecturales ont été élaborées à cet effet : le projet initial conforme aux vœux du client et un projet basé sur l'efficacité énergétique.

Resumen

El sector de la construcción es un gran consumidor de recursos naturales. La incapacidad de predecir el rendimiento con seguridad puede resultar en desechos insostenibles (por planificación excesiva) o en un deterioro prematuro costoso. La determinación del costo del ciclo de vida permite optimizar el rendimiento de edificios y otras estructuras durante toda su vida. Su valor ha salido a relucir por la utilización creciente de una especie de iniciativa privada de financiación en la que el promotor o constructor se encarga del funcionamiento y mantenimiento de la estructura durante un período acordado. El artículo presenta el concepto de costo del ciclo de vida según se utiliza en el sector de la construcción, explica brevemente como se determina el costo del ciclo de vida y algunos de los obstáculos para su utilización, y describe iniciativas para salvar estos obstáculos. Un estudio de caso ilustra el rendimiento de la inversión para reducir el consumo de energía. Para ello, se desarrollaron dos opciones de diseño: el diseño original según el pedido del cliente y una alternativa de eficiencia energética.

Use of the designation "life-cycle costing" has changed over a number of years. It has also variously been called whole-life costing, terotechnology, through-life costing, costs-in-use, total-cost-of-ownership, total-life costing, ultimate life cost and total cost. Life-cycle costing (LCC) and whole life costing (WLC) are commonly used terms today. The difference between the two is often taken to be that LCC is a sub-set of WLC and represents the period of interest that the cost analysis is aimed at.

A building owner will be interested in the costs of a built asset over its whole life, which could be measured in hundreds of years, whereas tenants will only be concerned with the costs they will have to bear during their tenancy – say 25 years. Public finance initiative (PFI) contractors will also be more interested in the life-cycle costs of the building for the 25- to 30-year contract period than in the residual life after it has been handed back.

In this article the term life-cycle costing (LCC) will be used because it reflects the majority of those who are interested in the technique. It is also used by the International Organization for Standardization.[1] Not surprisingly, given the history of the term, there are a number of definitions. "BS ISO 15686 Buildings and Constructed Assets – Service Life Planning Part 1:2000 General Principles" defines LCC as :

> *the total cost of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value.*

The UK's Construction Best Practice Programme (CBPP) provides another useful definition:[2]

> *...the systematic consideration of all relevant costs and revenues associated with the acquisition and ownership of an asset*

As its most fundamental level, it includes consideration of all costs and revenues associated with the acquisition, use, maintenance and disposal of a built asset.[3]

Life-cycle costing (LCC) is an estimation of the monetary costs of the funding, design, construction, operation, maintenance and repair, component replacement, and sometimes demolition of a building. It may be applied to new designs or to existing structures, in the latter case enabling residual life and value to be estimated. As different maintenance and repair and replacement operations take place at different times, incremental costs are converted to present-day value using a discounted cash flow approach.

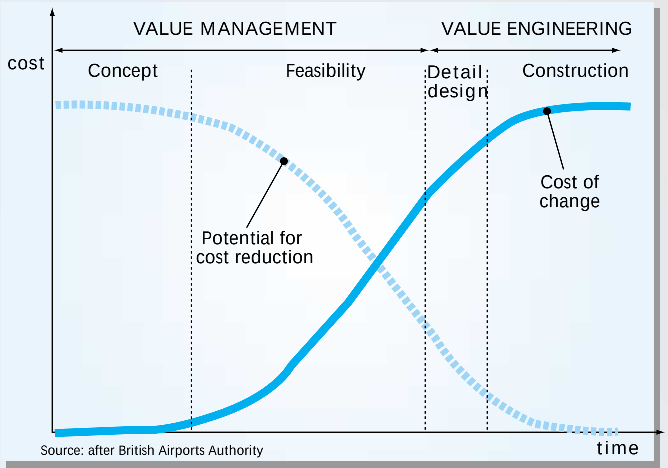
LCC relies on predicting when elements of the building and its services will deteriorate to a condition where intervention is needed, and what the discounted cost of each intervention will be. LCC calculations therefore depend on numerous assumptions, all subject to a degree of uncertainty.

Why use LCC?

Achieving excellence in design is essential for a construction project to deliver best value. Design is both a creative and a technical process. It should include the following components, each of which must be addressed appropriately:

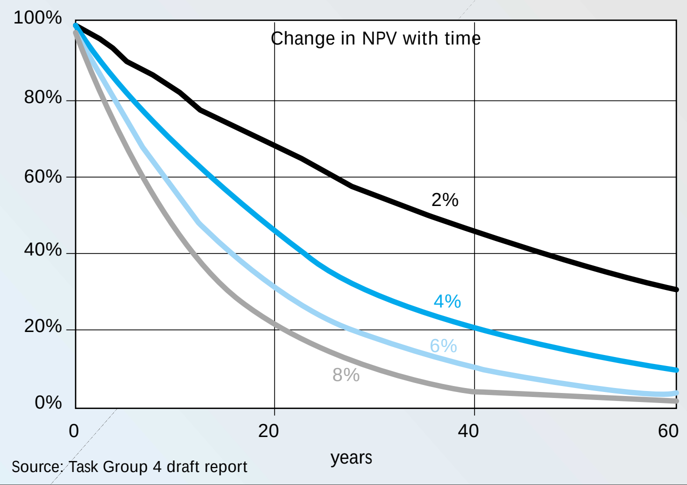
- *Functional design of the facility* to meet the needs of users and operations. This should result from a detailed assessment of the needs of the users and operations and how they may change over time, as well as how the facility will need to be altered to meet these changing needs.
- *Design of the complete facility* to address the environment for those who use, enjoy, operate, maintain or are otherwise affected by it, including aspects that impact on their health and safety. The design should address impact on the external global environment, as well as the facility's aesthetic, cultural and civic values.
- *Detailed design of each assembly and component*, whether manufactured on-site or in a factory, and whether it is a standard product or purpose-made or adapted for the facility.
- *Design of the entire construction process*, addressing how each component will be manufactured, transported and assembled to complete the facility. Maintenance of the facility (including details of how components can be replaced and/or repaired) should be addressed, as well as its ultimate disposal.

Figure 1
Opportunities for effective LCC



Source: after British Airports Authority

Figure 2
Effect of discount rate on NPV



Source: Task Group 4 draft report

◆ *Costing of projects.* This should include full life-cycle costs of the facility, as well as more immediate construction and project costs. The quality of both design and construction has the potential to greatly reduce life-cycle costs, including costs-in-use and eventual disposal of the built facility.

Decisions made early in the design process can have a considerable influence on life-cycle costs. Building orientation will influence the amount of solar heat gain and level of cooling required and the degree of shading; floor plate depth will influence the decision on whether the building needs to be air-conditioned as opposed to naturally ventilated; levels of insulation and air tightness will affect heat loss and energy costs; the number of floors will impact on costs of access for cleaning and maintenance; the number of entrances influences levels of security; and so on.

The earlier life-cycle costing can be considered in the procurement process, the more effective the outcome will be (Figure 1).

LCC is used in particular to:

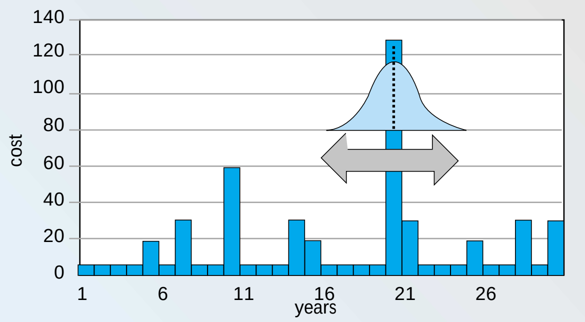
◆ determine whether a higher initial cost is justified by reductions in future costs (for new build or when considering alternatives to "like for like" replacement);

◆ identify whether a proposed change is cost-effective against the "do nothing" alternative, which typically has no initial investment cost but higher future costs.

Taking a life-cycle cost approach to procurement of buildings provides better certainty about future costs and the risks associated with them. Until recently, lending institutions have considered that most financial risk occurs during the construction period. Costs during construction can be affected by unexpected ground conditions, inclement weather, labour and materials shortages, time overruns, defects and poor budgeting. Financial institutions are now in the market for funding long-term PFI projects (lasting over 25 years) and they realize that there is even greater uncertainty during this period. Lack of understanding of how buildings perform, and when the need for intervention should occur to prevent failure, makes predicting future costs a long way ahead an unreliable exercise.

Owner-occupier clients are also coming to realize that the costs of building ownership can be a significant drain on company profits. They are looking for greater predictability of future costs before embarking on a construction project.

Figure 3
Uncertainty of forecasting time to intervention affecting spend



Source: Taylor Woodrow Construction Ltd

Table 1
LCC considerations

Stage of building life	Considerations for life-cycle costing
1. Acquisition by construction (new or refurbishment) – which would include costs of:	• land for the building, its clearance and related groundwork for new build • design, although this may often be included in the cost of construction with use of design and build type procurement • planning, regulatory and legal fees • construction, commissioning, fitting out and handover • in-house administration • interest or cost of money
Or Acquisition by purchase or rental – which would include costs of:	• purchase price • planning, regulatory and legal fees • adaptation to suit needs of the business • in-house administration • interest or cost of money
2. Operation (use and maintenance) – which would include costs of:	• maintenance, repairs, replacements of components and systems • cleaning • utilities and energy • churn (regular reconfiguration to suit changes in business or process operation – internal layouts of office buildings (typically change every five to seven years) • security and management • rates (and rent if required)
Income from use of asset	• income that may be generated through subletting of planned or surplus space
3. Disposal – which would include costs of:	• demolition • site clean-up
Income from disposal	• sale of interest in asset • sale of land • sale of materials from demolition

Source: based on Client's Construction Forum, *Whole Life Costing: A client's guide*, 2000

What needs to be considered when carrying out LCC?

The time-dependent stages of the life of a facility that need to be considered during the decision and procurement processes are: acquisition (including pre-construction and construction); operation (maintenance, replacement or refurbishment); and disposal (sale or demolition).[4]

At each stage consideration must be given to the basic elements of the facility – such as structure, envelope, mechanical and electrical services, finishes, and fixtures and fittings (Table 1).

The most important aspect when considering a facility's whole life is how it will enhance the core business operations that will take place in, on or around it. A very clear understanding of what those business operations currently are and how they might change in the future is necessary as a starting point, before it is possible to determine the facility's output performance requirements.

The life-cycle cost model for a specific project will be developed and subsequently updated by different parties according to the project stage reached and the form of procurement adopted. At project inception, the model might be developed in-house or by an external cost consultant. At tender stage, the bidder should take on or prepare the model if tenders are to be evaluated based on life-cycle costs. Where a framework contract is already in place, the framework supplier might be the most appropriate organization to develop the model from the outset.

A great deal of time can be spent going through lots of historical data from numerous sources in an attempt to get the most accurate information. This process is time consuming and normally shows that there are enormous gaps in the data available for creating life-cycle cost models. Where historical data is available, this may well reflect past mistakes in the industry such as lowest price. Irrespective of whether or not historical cost information is available, it is always preferable to estimate the costs from first principles and to use historical cost and performance information only as a check.

To account for different operations taking place at different times, incremental costs are converted to current costs using a discounted cash flow method that incorporates interest rates and inflation. This is particularly important when comparing options that have different replacement cycles.

The discounted cost rate, r, enables calculation of the discounted costs based on the future value of money as follows:

$$\text{Discounted cost rate, } r = \frac{(1 + \text{interest rate})}{(1 + \text{inflation rate})} - 1$$

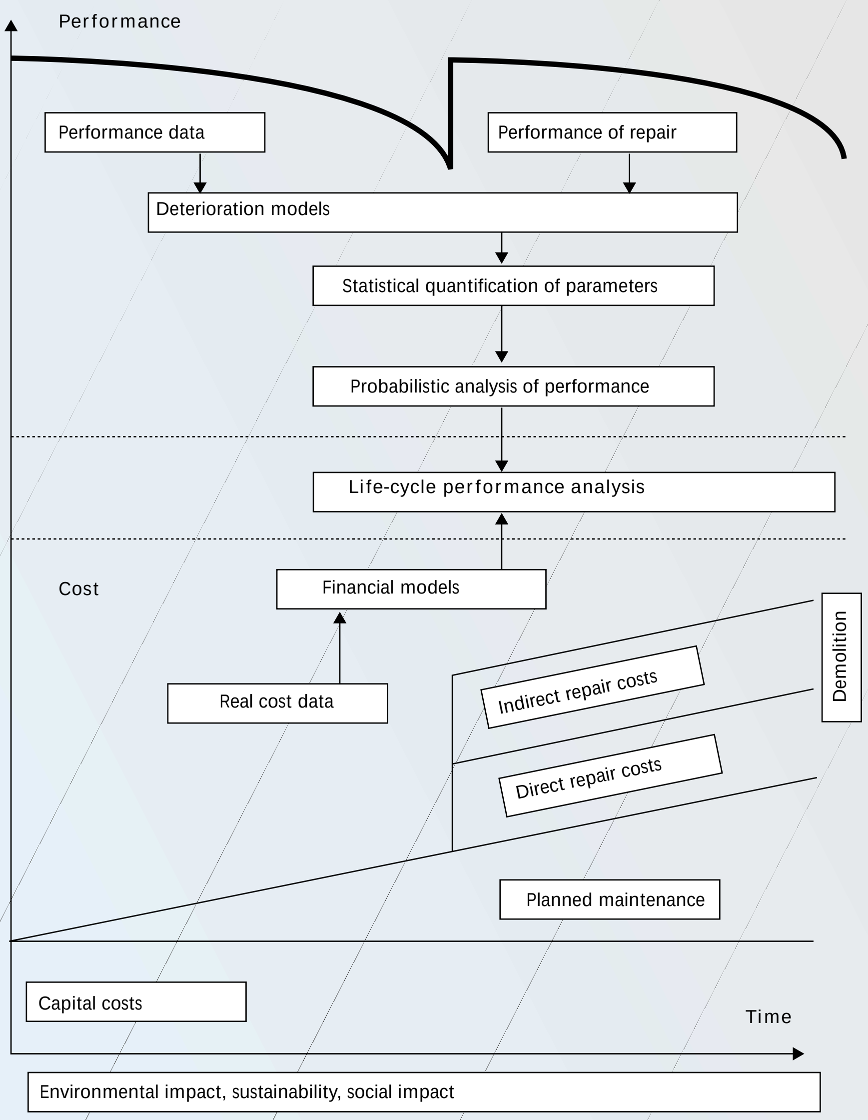
If the cost in year t is C_t and the discount rate is r, the life-cycle cost for a facility with a design life of N years, expressed as the cost at current value, is

$$\text{Present cost} = \sum_{t=0}^{t=N} \frac{C_t}{\left(1+\frac{r}{100}\right)^t}$$

The application of the principle of present cost (PC) is similar to net present value (NPV) and can cause difficulties in the analysis of WLC. Even at a low discount rate, the NPV decreases rapidly over time, as illustrated in Figure 2. This makes capital investment for long-term performance unattractive to a developer in monetary terms.

The discount rate is used to calculate the present value of a future income stream or cost – that is, the sum of money to be invested today in order to accumulate the amounts by the time they are needed. It is set by the client and includes the degree of risk on return required in a commercial context, or the rate of interest payable where loans are required to finance the construction work. If it is set too high, future costs will appear insignificant and will be favoured by the calculation. If it is set too low, higher capital costs will be discouraged but high operational costs may result. If inflation is taken into account in the discount rate and if rates are substantially different in practice, the calculation may lead to inappropriate choices.

Figure 4
EuroLifeForm: main features of life-cycle cost and performance model



Barriers to take-up of LCC

Life-cycle costing has often been dismissed because of lack of clear methodology and absence of data. A study in 1999 carried out by BRE on behalf of the Construction Research and Innovation Panel (CRISP)[5] found that these were the main reasons only 25% of clients used life-cycle costing. The lack of universal methodology and standard formats for calculating life-cycle costs, the difficulty integrating operating and maintenance strategies at the design phase, along with meaningless results, were considered barriers to the use of life-cycle costing.

"BS ISO 15686 Buildings and Constructed Assets – Service Life Planning. Part 1: General Principles" provides an overall framework that addresses the design of a building or construction with a view to its operation through the whole of its operational life. The approach requires long-term performance and overall operating costs to be addressed early in the design stage. It enables the design to be assessed against the client's long-term needs for the service life of the building.

A major impetus for producing this new ISO standard has been concern over the industry need to forecast and control the cost of ownership, as a high proportion of the life-cycle costs will have been set by the time of hand-over (Figure 1). It encourages involvement of all parties in the decision process for selection of components and systems, based on performance (durability) appropriate to the function and expected life of the asset. It focuses on the lack of data on durability, and provides a methodology for assessing and recording decisions on estimating the service lives of components where there is a lack of robust scientific and certified product data.

Service life planning is an integral aspect of life-cycle costing. The replacement cycles of sub-components that are expected to last less time than the overall service life of the main component, or the life of the building, are very sensitive to the calculation of life-cycle costs. Reliable forecasting of future replacements against the functional requirements of the building will reduce the possibility and costs of disruption to the business or processes being carried out in (or being supported by) the building or

Layout and height: reduced LCC and reduced energy loss

Options identified during design can generate savings in both initial capital cost and operating costs. For example, heat loss from a compact, single-storey school with a 2.4 metre storey height will be about 30% less than from one with an irregular layout and a storey height of 3.4 metres with the same floor area. The initial capital cost will also be about 20% less.

construction due to unexpected component failure (Figure 3). Service life planning assists in the identification of critical elements in the design. It can be applied to new and existing structures, although in existing buildings the residual service life of the retained elements will have to be assessed.

Some current initiatives to encourage use of LCC

TG4 Life-cycle costing

In the Communication from the European Commission, *The Competitiveness of the Construction Industry 1997*, 65 recommendations for action were included. The Tripartite Working Group (consisting of representatives of Member States, the Commission and industry) agreed an abbreviated list of priorities, including sustainable construction.

Three Task Groups (TG) were subsequently established:

- TG1: Environmentally Friendly Construction Materials;
- TG2: Energy Efficiency in Buildings;
- TG3: Construction and Demolition Waste Management.

Following completion of the individual reports of these TGs, a general report on sustainable construction, *An Agenda for Sustainable Construction in Europe*, was also drawn up and agreed.[6]

The general report contains a number of recommendations, one of which proposed that a fourth TG be set up to draft a paper on life-cycle costs in construction and to make recommendations concerning how these might be integrated into European policy making. Consequently, TG4 was established.

The terms of reference of TG 4 are to:

Draw up recommendations and guidelines on life-cycle costing of construction aimed at improving the sustainability of the built environment.

TG4 has yet to complete its work, but it is preparing a number of recommendations aimed at encouraging the development and adoption of a common European methodology for assessing life-cycle costing, supported by guidance and fact sheets. It also likely to recommend that contracts be awarded to the economically most advantageous tender, taking into account life-cycle costs.

This will compliment the work that has been undertaken by the Economically Most Advantageous Tender (EMAT) Task Group set up in July 2001 to develop a methodology for awarding construction contracts. This is an import step towards encouraging tender assessments and awards based on best value. The award criteria being recommended by the EMAT Task Group are:

- quality and life-cycle cost;
- the relationship (ratios) between quality, life-cycle costs and initial construction cost (the tender price);
- weightings for quality and life-cycle cost criteria;
- mandatory thresholds.

Reducing the cost of access for maintenance and accidents

An LCC analysis enables a designer to consider the possibility of reducing maintenance cost at no additional initial capital cost. This is achieved by improving accessibility to various building elements for foreseeable maintenance and replacement work, or by removing the need for access altogether.

The greatest savings can occur when:

- regular maintenance is avoided by redesign;
- entire cycles of maintenance are removed at high level, where scaffolding costs will often exceed the costs of the work to be carried out. Over 50% of all accidents in construction are a result of falls from a height.

Procurement routes such as prime contracting and PFI lend themselves more readily to being assessed on the basis of life-cycle costing, but involve lengthy and costly tendering processes.

Probabilistic approach for predicting life-cycle costs and performance of buildings and civil infrastructure (EuroLifeForm)

Some LCC thinking currently attaches a risk factor to interventions for replacements, but the risk is not usually time dependent. It may be assumed that there is a 1% chance of leakage through a cladding system over a 30-year life, but there is no indication of when the leaks may occur. To estimate the changing risk with time, a probabilistic approach is needed

EuroLifeForm is a European funded research project. The principal objective of the EuroLifeForm project is the development of a generic model for predicting life-cycle costs and performance. This will be applicable initially to the design of buildings and structures to optimize life-cycle costs and latterly to optimize interventions through maintenance and repair. The approach will be essentially the same, the principal difference being the input data for predicting performance. For existing structures decisions can be based on observed performance, while the design of a new structure must rely on background information.

The project primarily addresses technological and cost issues, but other factors such as environmental impacts are becoming increasingly important. Some of these factors are difficult to value in monetary terms, but qualitative methods of assessment are being investigated. Methods for multi-criteria decision making are being investigated in this context, to enable the client to optimize in relation to his own hierarchy of priorities and the weighting between them. The main features of the proposed EuroLifeForm life-cycle cost and performance model are shown in Figure 4.

The principal benefit of this project will be improved predictability in relation to the cost and performance of an asset. Uncertainties will always exist, but the intention is to enable these to be identified and quantified using a risk-based approach. By making possible more transparent and better-informed decisions at the design stage, this will lead to better value and more efficient use of resources.

References

1. www.iso.ch/iso.
2. CBPP (1998) *Introduction to whole life costing* (http://cbp.idnet.net/).
3. Kishk, M., et al. (2003) *Whole life costing in construction: A state of the art review* (RICS Foundation).
4. Client's Construction Forum (2000) *Whole Life Costing: A client's guide.*

Prime contracting

Historically, the UK Ministry of Defence has used the term "prime contracting" to describe single point responsibility. Although this originally referred to weapons and equipment procurement, the term is equally valid for construction procurement.

Prime contracting recognizes that industry is best placed and best qualified to manage the complete task.

The prime contractor will be responsible for:

- sub-contract selection;
- procurement management;
- design, coordination and overall system engineering and testing;
- planning, programming and cost control;
- total delivery, fit for purpose and in line with through life cost predictions.

5. Clift, M. and K. Bourke (1999) *Study on whole life costing*. BRE Report 367, Building Research Establishment (BRE)/Construction Research and Innovation Panel (CRISP).
6. These reports are available on the European Commission's website (http://europa.eu.int/comm/entreprise/construction/index.htm).

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Case study on comparative life-cycle costs: client-compliant bid versus energy efficient design (barrack accommodation for the UK Ministry of Defence)

The client wanted to build low-energy sleeping accommodation for soldiers, but needed assurances that any additional initial capital cost would be justified. Building Research Establishment (BRE) used life-cycle costing to demonstrate value for money by adopting a sustainable construction approach. For the exercise, two design options were developed: the client-compliant (original) design and an energy efficient option. The overall project value is in the order £4.0 million.

The results of the analysis show that initial additional capital spending of £72,648 on the energy efficient option produces an LCC saving of over £236,945 (discounted at 6%) at current prices. The additional costs mainly cover redesigning the building to reduce air exfiltration (leakage) and to increase wall and roof insulation and building mass. Savings were made to the heating system by adopting a heat recovery approach, taking advantage of occupancy patterns, and realizing the passive environmental control from utilizing the additional building mass and the effect of increased insulation.

	Client-compliant option £	Alternative energy efficient option £	Saving/ extra £
Initial capital cost of elements analyzed	1,623,199	1,695,848	-72,648
Life-cycle cost (LCC) over 60 years	4,272,398.85	2,870,913	1,401,485
Net present value (NPV) of life-cycle cost over 60 years	2,608,191	2,371,245	236,945

Energy/utility costs

The following costs have been estimated using CYMAP, an industry recognized energy use software. All energy and water consumption figures are based on calculations carried out by the design team services engineer. Costs are based on local rates provided by the utility providers.

Yearly costs

	Client-compliant option £	Alternative energy efficient option £	Saving/ extra £
Gas	19,252	7,280	11,972
Electricity	23,332	18,004	5,328
Water	7,304	4,562	2,741
Total	49,888	29,846	20,041

The gas cost takes account of an estimated additional £1000 per year saving in hot water heating cost through use of low water flow showers.

Total energy/utility cost (non-discounted over 60 years)

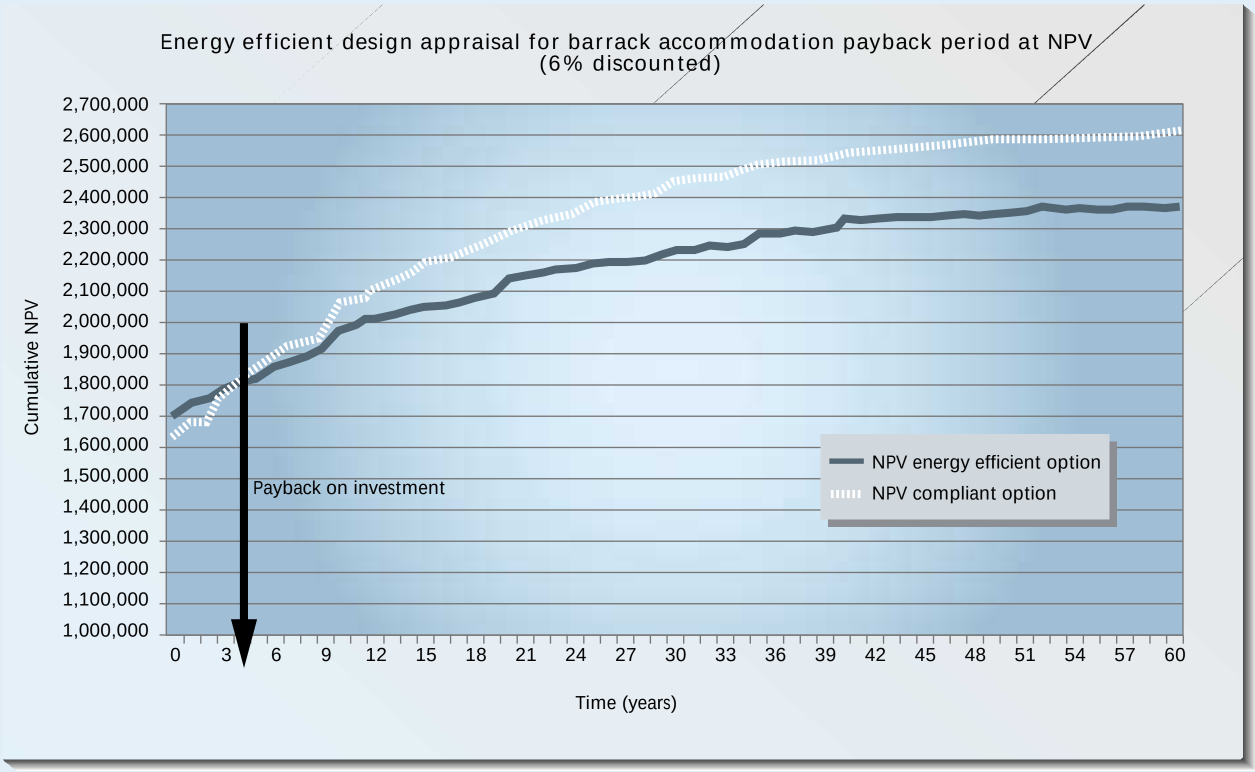
	Client-compliant option £	Alternative energy efficient option £	Saving/ extra £
Gas	1,155,120	436,800	718,320
Electricity	1,399,920	1,098,244	301,676
Water	438,242	273,748	164,493
Total	2,993,282	1,808,792 1	184,489

The graph below shows the payback period for the selected elements, which will occur in year 5.

Partnering principles are key to the process

The pricing model is a target cost incentive fee arrangement. This is a simple arrangement under which the parties share, on a pre-determined basis, any excess or savings of actual costs, thus providing a strong financial incentive to improve performance. It is an underlying premise of prime contracting that the contracting parties will buy into the principles of shared goals and will receive a fair profit for delivering what the client wants, when it wants it, at the agreed price. To make this concept work to the maximum advantage of both parties, long-term contractual relationships should be considered.

The UK National Health Service has adopted a similar approach, calling it ProCure21.



Land use and sustainable buildings: design and construction in southern Brazil

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Summary

In recent years several activities related to sustainability in the built environment have been carried out in the postgraduate civil engineering programme at the Federal University of Rio Grande do Sul in southern Brazil. Some have been related to education and others to design and construction. This article presents the overall conceptual framework for projects that apply sustainability principles and key overall objectives. A recent project (a proposal for a technical school) illustrates how the framework and its objectives can be addressed in the context of a specific project. Other research and design activities are also briefly described. There is a short discussion of barriers to incorporating sustainability issues in land use planning and project design in developing countries.

Resumé

Depuis quelques années, plusieurs activités en rapport avec la durabilité de l'environnement bâti ont été menées dans le cadre du cursus de génie civil de 3e cycle de l'Université fédérale de Rio Grande do Sul, dans le sud du Brésil. Certaines étaient liées à l'enseignement, d'autres à la conception et à la construction. L'article présente le cadre conceptuel général des projets appliquant les principes de développement durable et les principaux objectifs. Un projet récent concernant une école technique montre comment le cadre et les objectifs peuvent être envisagés dans le contexte d'un projet spécifique. L'auteur évoque succinctement d'autres activités de recherche et de conception et procède à une courte analyse des obstacles qui, dans les pays en développement, freinent l'intégration des questions de développement durable au processus d'aménagement du territoire et d'élaboration des projets.

Resumen

El programa postgraduado de ingeniería civil de la Universidad Federal de Rio Grande do Sul en el sur de Brasil ha llevado a cabo en los últimos años varias actividades relacionadas con la sostenibilidad del ambiente construido, algunas relacionadas con la educación y otras con el diseño y la construcción. El artículo presenta el marco conceptual general de los proyectos sobre edificios más sostenibles y los objetivos clave de estos proyectos. Un proyecto reciente, una propuesta para una escuela técnica, muestra cómo abordar el marco conceptual y los objetivos en el contexto de un proyecto específico. También se reseñan otras actividades de investigación y diseño. Una breve discusión trata sobre los obstáculos para incorporar cuestiones de sostenibilidad en la planificación del uso de tierras y en el diseño de proyectos en países en desarrollo.

The environmental impacts of the construction sector are huge. Moreover, the challenges this sector must meet in the search for sustainability are not restricted to the environment. They also include social, economic, cultural and political dimensions. Sustainability issues are relatively new to the Brazilian construction sector. Education and demonstration projects are two means of increasing awareness. Such activities, and the process of developing them, can help produce major strides towards bridging the gap between available knowledge and local practice.

NORIE, a section of the Postgraduate Programme in Civil Engineering devoted to construction, is working on both these issues. Sustainability principles as applied to design and construction are taught at the undergraduate and postgraduate levels; for the latter students, an MSc course in civil construction offers opportunities to engineers, architects and even agronomists interested in sustainable construction. Recent MSc dissertations, for example, have dealt with urban waste management, low-cost solar collectors, use of timber for low-cost sustainable housing, design of more sustainable houses and communities, local materials with low environmental impact, and productive landscaping in urban areas.

The team at NORIE has also been developing several research and design activities to apply the principles of sustainability being taught. These projects are carried out in the following overall conceptual framework:

- The principles of sustainability should direct the design process;
- A systemic approach should be adopted;
- As far as possible, the process should consider closed cycles for materials and energy flows;
- Designers should try to identify the processes occurring in nature and apply their principles (design with nature);
- As humans and human sustainability should constitute the main purpose of each project, use of products known to pose threats to human health or the surrounding environment – at any point in their life cycle – must be eliminated or, if alternatives are not available, minimized;
- As human sustainability requires nature preservation in ways we are just starting to understand, what applies to humans should also apply to the millions of other species with which we share this planet.

The key overall objectives of this conceptual framework are:

- minimizing materials and energy use and maximizing the elements of healthy buildings;
- promoting social commitment and responsibility so as to provide employment and income to as many people as possible within a context of economic feasibility;
- stimulating development and research on production options that are in harmony with local cultures, again with the aim of generating jobs and income;
- whenever possible, using participatory processes including the client and final users;
- taking into account the impacts of all products used over the entire period of production and use; the concepts of life-cycle analysis and ecological footprints should be familiar to designers;
- ensuring that more sustainable construction is preceded by more sustainable design projects, as well as adequate instruction of those who will execute the work;
- follow-up, so that the finished project is sustainably managed by personnel trained for this purpose.

NORIE's latest project: proposal for a technical school

In December 2002, NORIE was invited to address sustainability issues with respect to a proposed technical school whose design was already approved by the Education Ministry. Having heard about the group's activities, the secretary of education at Feliz, where the school was to be built, challenged NORIE to give the school a more sustainable infrastructure. This case throws light on how NORIE addresses the above framework and objectives in the context of a specific project.

The Feliz school is intended to serve youngsters from towns throughout the Caí River watershed. It will offer technical education in areas of interest to the region such as biotechnology, agro-industry, construction ceramics and information technology. The school will be administrated by the Fundação de Educação Profissional do Vale do Rio Caí, a foundation whose members include representatives of the 20 regional municipalities. The top priority was "to guide the actions of the school aiming at sustainable development of the region, focusing on environmental preservation."

The school is expected to have up to 2000 students, split into three groups attending morning, afternoon and evening classes. The total area of the building is around 3670 m^2 on a plot of some 62,000 m^2 (about 75 metres wide and 825 metres long), mostly covered with native trees.

The team stressed that since the design project had already been approved, NORIE's contribution would be limited to sustainability "cosmetics." After discussions that included other actors interested in how the school turned out, it became clear that a new, more sustainable design would better meet the aspirations of everyone involved. Less than a month after the first meeting, all parties met again to discuss issues and ideas for a new design. Everyone agreed to take the opportunity to develop a design for the school that would be more in accordance with sustainability principles.

NORIE was asked to submit a new design. Several postgraduate students whose main interests involved more sustainable buildings and communities were invited to join the working group examining alternatives.

The original design had given no consideration to use of more sustainable materials or passive solar architecture. Other critical points were equally easy to identify:

- The buildings were to be a cluster of four blocks, with no attention paid to solar orientation, insulation or cross ventilation; existing vegetation was not taken into account in their siting, which in addition would require considerable unneeded earth moving;
- Large parking plots (much larger than needed) were included, also requiring considerable earth moving and tree felling;
- There was a lack of integration between the original landscape and the school buildings.

Tables 1 and 2 show the guidelines adopted for the new project, which are in line with the principles of Fritjof Capra regarding *ecoliteracy* and of John Lyle concerning *regenerative design*,[1] and the emphasis on green schools in recent publications.[2]

The guidelines in turn were translated into specific elements of the school design. For instance, under Food: crop rotation, mulching for soil protection; under Energy: use of solar energy and wood cooker.

Table 1
Proposed technical school: general project guidelines

• Maximum efficiency in use of available resources
• Multiple functions for each element introduced
• Consideration of nature as a model
• Interaction with environmental educators from the design stage
• Openness (of auditoriums, visiting areas, trails, etc.) to the local community
• Respect for local cultural and social characteristics

Other research and design activities

Challenging opportunities for students were created when new research projects were begun in 1999. They arose from an international Design Ideas Competition organized by NORIE in 1995, with funds from the Brazilian government, involving sustainable housing for the poor.[3] The first research project related to sustainability was to design a small settlement demonstrating the use of sustainable technologies. Called the Experimental Centre for Sustainable Housing Technologies (CETHS),[4] this project was followed by, or developed together with, others as briefly described below.

The pilot community, whose design was inspired by the results of the competition, was intended to become an experimental centre for sustainable housing technologies. The first eight units were completed in 2002 in Nova Hartz, a town about 90 km from Porto Alegre, the capital of the state of Rio Grande do Sul. Once concluded, this project will likely be unique in South America for having aggregated on one site a whole group of strategies that are usually only partly developed and at different locations. Even more important is the link between the project and Brazil's social reality, and the fact that the expected results will not just be technical but will include organizing and mobilizing the target groups and providing alternatives to the critical conditions in which most of Brazil's low-income population lives. The centre, if successful, will be a living model for a wider public.

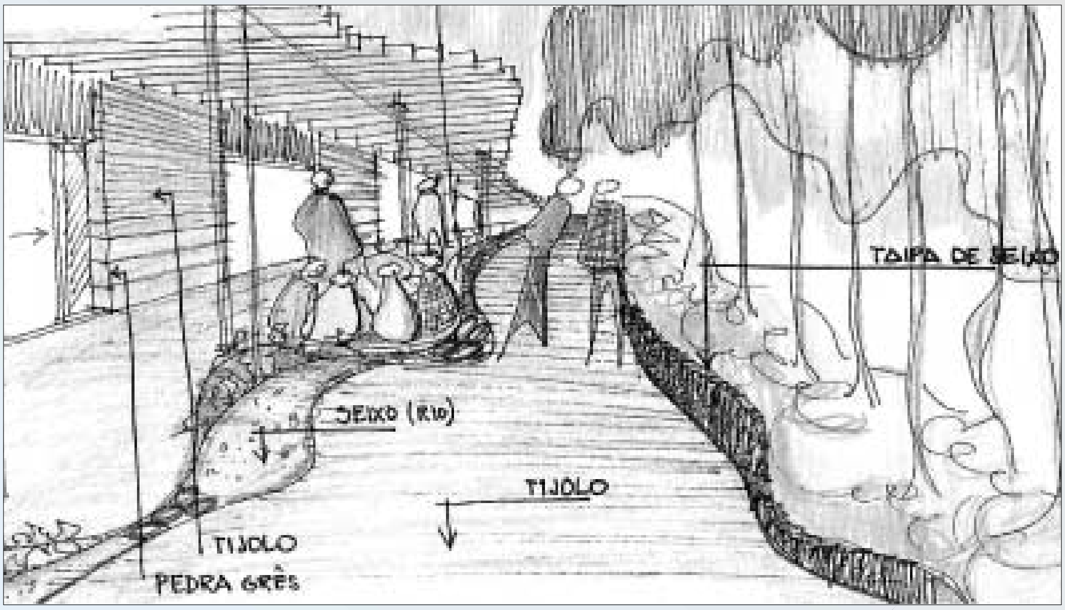
The strategies used in CETHS's conception and design were:

- design that maximizes the community's autonomy in terms of energy, waste, food production and water;
- local food production, both for local consumption and for income generation;
- a role as demonstration centre, with the settle-

Table 2
Proposed technical school: specific project guidelines

Materials	**Food**
Local	Use of local skills for plant and animal management
Culturally accepted	Local production
Non-toxic	Productive landscape
Recycled or potentially recyclable or reusable	Diversity of cultures
Durable	Identification of community's needs, diet and nutritional imbalances
Suitable for self-construction	Incentives for organic food production in region
Small ecological footprint	Organic food production at the school
School design	**Location**
Flexibility	Adaptation to geomorphology
Comfort. The main challenge is finding energy-efficient solutions for the hot months, making it important to include cross-ventilation and control of solar radiation (mainly by shading with deciduous trees); daylighting, noise control, etc. are also important	Use and preservation of native species
Universal accessibility to disabled people	Fitting buildings to climate
Respect for regional architectural characteristics	Organic design
Adequate habitable areas outdoors as well as indoors, including spaces near buildings where internal classrooms could be expanded on occasion	Adequate scaling of private spaces to students and open spaces to local community
Energy	**Water**
Efficient use	Sensible use
Use of sustainable sources	Optimum management inside the system
Matching of sources to needs (e.g. biogas generation and biomass production for cooking and occasional heating, solar radiation for water heating, wind energy for water pumping)	Reliance as far as possible on internal collection
Offsetting of non-renewable sources used by internal production	Reuse
Waste	**Social and economic issues**
Reduced consumption of goods that contribute to waste generation	Income generation from recycling of solid waste
Use of organic solid waste	Provision of multiple spaces for social interaction
Recycling of organic waste	Empowering of community in the decision process
Reuse of "grey water"	Community education Biological wastewater treatment

Preliminary sketch for the school: outdoor circulation



of them. This prototype is on the university campus, and at the time of writing monitoring was about to start.

The "more sustainable house" prototype incorporates the following features:

◆ passive solar architecture;
◆ low-cost solar collectors for water heating, using inexpensive and economical equipment. The idea is to use solar-heated water mainly for the shower, instead of the electric shower heaters generally used in Brazil. A NORIE study of more than 300 housing units found that electricity consumption for water heating in the relevant type of housing represented over 35% of total electricity use for the dwelling;
◆ use of low-cost local materials and reuse or recycling of materials from demolition;
◆ use of vegetation for shading and food production. For example, the west façade is covered with vines, which allows solar radiation to penetrate during cold weather and fruit to be grown for consumption by residents;
◆ water-saving strategies for bathroom and kitchen, including collection and recycling of rainwater for toilet flushing and garden irrigation. Water is collected on the roof and stored in tanks near the bathroom, which is built with simple materials. Using rainwater to flush toilets should reduce treated water consumption by more than 40%;
◆ use of elements and components suitable for do-it-yourself building;
◆ biological treatment of wastewater through combined use of septic tanks, sand filters, reed beds and aquaculture ponds.

ment being open to guided public visits;
◆ building design that follows the principles of bioclimatic architecture (in which a satisfactory level of comfort is achieved with a minimum of mechanical equipment fuelled by non-renewable energy) and minimizes the environmental impact of materials;
◆ an edible and aesthetic landscape in all common and individual areas;
◆ natural drainage for absorption of rain run-off;
◆ no incentives for private transport, but instead narrow roads favouring pedestrians;
◆ cul-de-sacs, encouraging only local traffic;
◆ a green belt for food production, environmental control and community privacy;
◆ a community centre encouraging participation by all inhabitants in community decisions;
◆ adequate infrastructure for the local management of solid and liquid waste.

The first aim of the team engaged in the conception of CETHS was to design, build and monitor performance of a prototype house before building the houses in the settlement.[5] Before this was completed, the mayor of Nova Hartz asked NORIE to proceed with construction of the low-cost, more sustainable housing he knew was being designed. Thus the eight housing units were built before a prototype house was monitored. However, the team stuck to its aim of building a prototype that could be properly instrumented, without occupation, and checked against the eight occupied houses and their residents' perceptions

Prototype house built on the university campus

Bela Vista Biological Refuge

In the second semester of 2000, NORIE was asked to submit design proposals for remodelling the Bela Vista Biological Refuge (RBV), part of the Itaipu Dam complex at Foz do Iguaçu in southern Brazil, on the border with Paraguay. RBV[6] is one of five such refuges on the shores of the Itaipu reservoir. Their purpose is to regenerate areas affected by the dam and to preserve native species. RBV (1920 hectares) is used for reproduction of wild animals, production of seedlings to reforest the shores, experiments with flora and fauna, and environmental education.

Given the importance of environmental education at RBV, both the structures at the refuge and the whole built environment are supposed to embody methods that are less damaging to the environment and more efficient in use of materials and energy.

In response, NORIE came up with a general theme in which design of the outdoor areas, buildings (or equivalent) and equipment was inspired by the four "basic elements": earth, water, fire and air. This would not only guide the designers, but would also be the basis of a user-friendly "language" for outreach to the expected 50,000 visitors a year.

This concept led to the formulation of several strategies to generate an environmentally sound product, as well as to increase understanding of the technologies used and the role of each element and of nature as a whole. Regarding *earth*, for example, the beauty of vegetation on green roofs is seen as stimulating visitors' curiosity. The proposal incorporates roof gardens, roof ponds, heat exchangers and sensory gardens (with plots of vegetation dedicated to experimentation with each of the senses – sight, taste, smell, touch and hearing).

In developing the projects described above, the NORIE team found that the first and primary barrier to incorporating sustainability issues in land use planning and project design is lack of knowledge of sustainability in general by all or most of the main actors. The traditional way of thinking, the absence of a more systemic way of viewing life, seems to block understanding of how important a shift towards a more sustainable way of living is for survival of the human species. NORIE's activities are in demand among people with a vision – a more sustainable, systemic or holistic vision. But in Brazil, as in other developing countries (though it must be stressed that the phenomenon is not restricted to developing countries), addressing the lack of education about sustainability is the main challenge.

Notes

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Sustainable building services in developing countries: the challenge to find "best-fit" technologies

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Summary

Intelligent energy efficiency technologies in developing countries can be assessed on the basis of best-fit criteria (usable controls for occupants, minimum conflicts in operation, inherently energy efficient, and easy to build, maintain and operate). This article argues that ostensibly energy efficient solutions will not perform as intended unless they are appropriate for the climate, are well detailed, installed and commissioned, and are of a level of complexity that can be understood by managers and users of the building. Relevant low-energy technologies include greywater recycling systems, passive and active thermal storage, and ground-source heat pumps. Successful export of such technologies on a wide scale will depend on developed countries setting an example at home. For low-energy building design to have a lasting momentum, commercial clients and governments on both sides of the economic divide need buildings that broadcast a commitment to proven – rather than theoretical – energy efficiency.

Résumé

Les technologies intelligentes d'efficacité énergétique des pays en développement peuvent être évaluées à partir de critères dits les plus adéquats (boutons de réglage utilisables par les occupants, minimum de difficultés dans l'utilisation, efficacité énergétique intrinsèque, facilité de construction, d'entretien et d'exploitation). L'article soutient que les solutions à haute efficacité énergétique ne donneront pas les résultats attendus si elles ne sont pas adaptées au climat, correctement expliquées, installées et mises en service, et si leur niveau de complexité n'est pas à la portée des gestionnaires et des usagers du bâtiment. L'auteur analyse les technologies à bas profil énergétique, notamment les systèmes de recyclage des eaux grises (eaux usées traitées), le stockage thermique passif et actif et les pompes à chaleur géothermiques. L'exportation à grande échelle de ces technologies dépend de la capacité des pays développés de montrer l'exemple chez eux. Pour que les projets de construction à bas profil énergétique se généralisent de façon durable, les maîtres d'ouvrage et les gouvernements des deux côtés de la fracture économique ont besoin de bâtiments qui témoignent d'une recherche d'efficacité énergétique réelle, plutôt que théorique.

Resumen

Las tecnologías inteligentes de eficiencia energética en los países en desarrollo se pueden evaluar a base de criterios de "mejor concordancia" (controles prácticos para ocupantes, conflictos mínimos en el funcionamiento, eficiencia energética inherente, y fácil de construir, mantener y manejar). El artículo plantea que soluciones que son eficientes claramente en materia de energía no producirán los resultados esperados a menos que sean apropiadas para el clima, que se hayan detallado, instalado y encargado correctamente y cuyo nivel de complejidad pueda ser comprendido por los administradores y utilizadores del edificio. Se analizan tecnologías relevantes de bajo consumo energético, por ejemplo, sistemas de reciclaje de aguas grises, almacenamiento termal activo y pasivo y bombas de calor geotérmico. El éxito de la exportación a gran escala de estas tecnologías dependerá del buen ejemplo que den los países desarrollados en casa. Para que el diseño de la construcción de bajo consumo energético tenga un impulso perecedero, los clientes comerciales y los gobiernos de ambos lados de la línea divisoria económica necesitan edificios que propaguen un compromiso a la eficiencia energética comprobada en vez de teórica.

Greenhouse gas emissions do not respect national frontiers. Developed nations export their technology and skills, and in turn the developing nations are highly desirous of the functionality of construction that the West can offer. With international carbon trading becoming a very real prospect, the onus is on nations with the design knowledge, products and installation skills to ensure that buildings in the developing world also benefit from robust, energy efficient solutions.

In the UK, buildings of all kinds account for around 50% of total greenhouse gas emissions.[1] Much of these emissions is generated by consumption of gas and electricity for space heating, refrigeration, mechanical ventilation and humidification systems, along with electric lighting, catering equipment, and what are known as small power loads, such as computers and general office equipment. The onus is clearly on those who design and construct buildings (and those who operate them) to ensure that the normal state for all this equipment is one that is inherently energy efficient.

The problem is, there are few examples where a technological advance, often intended to improve quality of life, has not led directly or indirectly to an increase in energy consumption. Indeed, some innovations intended to reduce energy consumption have had the opposite effect. Therein lies a threat: where developed countries lead, developing countries are sure to follow.

Technology in itself, then, is not a solution. Neither is it wise to tot up the theoretical savings in carbon emissions from the application of ostensibly energy efficient technologies – be they photovoltaics, greywater recycling plant, natural ventilation devices or low energy lamps – and believe that net savings will automatically result. Often the reverse is true, with the technology not performing either due to shortcomings in design, commissioning or management, or simply because of extended hours of operation. Some energy saving technologies are simply switched off because they are too complex for building owners to manage.

Such "revenge effects" of so-called smart technology are rife. Even buildings in the UK lauded for their intelligence or their low energy attributes have subsequently proved to consume more fossil fuel than their designers intended.[2]

If developed countries are to invest in providing low energy infrastructures for the developing world, we need to know what techniques and technologies are appropriate for each context. We also need to be sure that the intrinsic complexity of solutions will be well within the capabilities of the people subsequently responsible for their operation and maintenance. Such solutions can be called "best-fit" technologies.

Best-fit technologies

A best-fit technology can be defined as a solution that is appropriate for a particular context. Technical solutions need to be assessed for their functionality for the user, for reliability in operation, for buildability (given local skills and resources) and for manageable complexity. As with any technology,

Installation of thermal rock stores at Harare International School in Zimbabwe: supply air is drawn through these cages from left to right (note deep solar shading created by extension of roof as veranda) (©ARUP/Mike Rainbow)

Turbine-type wind cowl on the roof of the Harare International School (©ARUP/Mike Rainbow)

from a brick to a computerized building management system, the commodity must be available and obviously must be suitable for the climate.

Any product or solution that passes these tests could be defined as *intelligent*, if only on the basis that wisdom has been applied to the selection and management criteria.

Building intelligence certainly has little to do with complexity, with electronics or with automation. A technically smart item of kit used in the wrong context will probably default to *stupid* modes of operation. If a technically complex solution is specified on the basis that it is a fit-and-forget item, but proves to be a fit-and-manage item, then its success is out of the hands of the designer and in the laps of the poor souls running the building.

Research also shows that the best intelligence in buildings resides with the occupants.[3] If so, the challenge for designers and manufacturers is to support them with appropriate and understandable systems which have readily-usable control interfaces, and which give immediate feedback on their performance.

Given this range of conditions for best-fit technology – usable controls for occupants, minimum conflicts in operation, inherently energy efficient, and easy to build, maintain and operate – which ones are most applicable for use in developing countries?

Table 1 lists the virtues and drawbacks of various building technologies systems in the context of their application in developing countries. A more detailed review of some of these systems is given below.

Fabric energy storage

Given the inherent problems of operating mechanical building services in regions of the world where energy sources may be unreliable, along with the likely lack of engineering skills to maintain those services, it makes sense to adopt passive solutions wherever possible. The most obvious approach is to use the building fabric as a medium for storing, cooling and heating energy.[4]

Most continental climates tend towards quite wide diurnal swings in temperature; in Zimbabwe, for example, summertime temperatures can range from 16°C at night to 33°C during the day, which gives considerable scope for using thermal mass to control internal temperatures without recourse to mechanical cooling or heating.

Heavyweight structural elements are the simplest form of thermal storage system, their primary characteristic being their slow thermal response, which enables the structure to be used as a medium for storing cooling and heating energy. Exposure of such structural elements to the occupied spaces serves to control the diurnal swings in environmental temperature and provide more of a steady-state internal environment.

However, most building fabric energy storage systems need control over the heat flows in and out of the building, and over the time and place of release. This requires active energy storage, which in turn may require air flow control devices and quite possibly mechanical fan power.

Wind-powered ventilation cowls on roof of PE hall at Harare International School (©ARUP/Mike Rainbow)

Active energy storage

Active energy storage is where controls are used to regulate the flow of heat energy into and out of a building. This can be anything from penny-flap dampers controlled by occupants to complex mechanical ventilation systems that use air to charge and discharge the structure with heat energy.

A good example of how this can be applied to developing countries is the system designed by consulting engineers Ove Arup and Partners and architect Pearce Partnership for the Harare International School in Zimbabwe. Here, the active energy storage system is based on cages of loose rock that act as thermal batteries.

Situated within the tropics, Harare International School was built in 1998 to meet the schooling needs of expatriate children from over 50 nations. The school block features 12 classrooms and laboratories, an art block, and a central music room with associated stage and amphitheatre. Supply air to the school's classrooms is pumped through steel cages containing locally-sourced granite pitching stone, after which the tempered supply air enters the classrooms through low-level grilles.

During summer nights cool air is blown through the building via the rock stores, which are cooled by the very cold night air that is a feature of the local high veld climate. The ventila-

Table 1
Benefits and shortcomings of energy saving technologies for developing countries

Technology	Characteristics	Functionality	Degree of fit-and-forget (reliability)	Buildability	Maintenance requirement	Overall suitability for developing countries	Intelligence: 1 star = stupid, 5 stars = smart
Natural ventilation	Uses natural pressure differences to ventilate internal spaces	High for simple buildings, but pollution/daylight conflicts need to be managed	High, but vents, cowls and windows are not fit-and-forget	Very good, no need for services plant	Low, but vents, windows and any automated actuators need maintenance	High, but dusty air in hot climates cannot be easily filtered	*****
Mechanical ventilation	Uses fan energy to control air flow into the building	Medium to high, needs fan power, but heat can be recovered	Medium, complex controls require good management	Good if kept simple	Medium, plant needs maintaining and a supply of filters is needed	High where a system can be used for active thermal storage and powered by renewable energy	***
Mixed mode ventilation	Uses a combination of fans and windows as needed, for ventilation	Medium to high, offers flexibility between natural and mechanical ventilation	Medium, needs careful attention to controls	Good if kept simple	Medium, plant needs maintaining and a supply of filters is needed	High where a system can be used for active thermal storage and powered by renewable energy	****
Rainwater recovery	Recovery of rainwater for drinking or flushing	High, but dependent on rates of rainfall	Medium	Good (simple and component-based)	Low for flushing, high for drinking	Medium to good, depending on rainfall	****
Greywater recovery	Recovery and storage of washing water for flushing purposes	High, for areas with low rainfall or with unreliable supplies of drinking water	Low	Reasonable (component-based)	High (for monitoring, filters, and disinfectant)	Low to medium, depending on the severity of context	**
Composting toilets	An alternative to the flush toilet where effluent is stored and composted	High, for areas without a sewerage system	High	Good (few moving parts, self-assembly)	Low and easy	Very good, for systems not reliant on an electrical supply to heat the compost	****
Passive thermal storage	Exposed building structure that controls solar gains and stores heating and cooling energy	High, climate dependent	High	Good, but may be dependent on materials availability	Low	High	*****
Active thermal storage	Mechanical or semi-mechanical system to control rates of energy storage and discharge	Medium, may need energy for fans and controls; climate dependent	Medium, can fail to perform without good control	Good, but requires fine tuning to deliver results	Low to high, depending on complexity	Good, but may be fragile without robust controls, needs facilities management ability	***
Ice stores	Maximizes off-peak refrigeration energy to charge an ice store for release of cooling energy during the day	Low , higher overall energy penalty	Very low, complex systems need constant management	Medium (component-based, but takes up much space)	High: chillers, pumps, pipework and ice vessels	Low, often fragile without skilled management, needs good controls and financial acumen	*
Ground-source heat pumps	Uses latent heat in the ground to power a heat pump in cooling or heating mode	Medium to high	Medium	Low to medium (component-based, but boreholes can be high cost)	Medium, heat pump and controls need maintaining; boreholes can silt up	Low to medium, closed circuit boreholes most reliable, open circuit may provide flushing/irrigation water	***

tion system purges the rocks of heat to 20°C, providing 4-5°C pre-heat the next morning. The system also functions efficiently during the winter months, when Harare experiences chilly mornings followed by pleasantly warm afternoons. By operating the low energy fans during daytime hours only, afternoon heat is stored in the rocks, subsequently producing several degrees of preheating to the early morning supply air. In operation, the classrooms are consistently 3-5°C cooler than the external temperature. Pressure loss through the rockfill is said to be less than 10 Pa/m^2.

As this type of scheme was the first of its kind, it was necessary for the engineers to establish the most effective fill material for the rock stores. A test bed was fabricated, so that different options could be assessed in terms of rates of storage and release of energy and the aerodynamic resistance at various flow rates. Various recycled fill materials were considered at this stage, including steel grinding mill-balls, water-filled milk cartons, building rubble and stacked paving slabs. In the art block passive ventilation is promoted using a specially engineered wind-driven extractor. Likewise, the sports building benefits from a pair of periscope-shaped wind cowls that turn in opposition to each other, and in so doing provide passive supply and extract.

Climate is the big decider for this kind of simple energy storage system. Rockstore systems work best in a continental climate, with a large dirunal swing of around 10K – typical of continental climes within plus or minus 30° latitude. This would cover South Africa, Zambia, Kenya, Ethiopia and many areas of Central America including Mexico City and Guatemala. Tehran and Kabul are also close to this 30° limit.

This installation successfully met the requirements of intelligent, best-fit technology: easy to source and build, easy to maintain, and reliable in operation. It can also be easily replicated without having to import specialist skills or equipment.

Ground-source heat pumps

Ground-source heat pumps are another way to generate heating and cooling energy while reducing reliance on sources of primary energy. In effect, heat pumps use the vapour compression cycle to generate heat across a wide temperature range that enables it to be used in either a cooling or heating mode.[5]

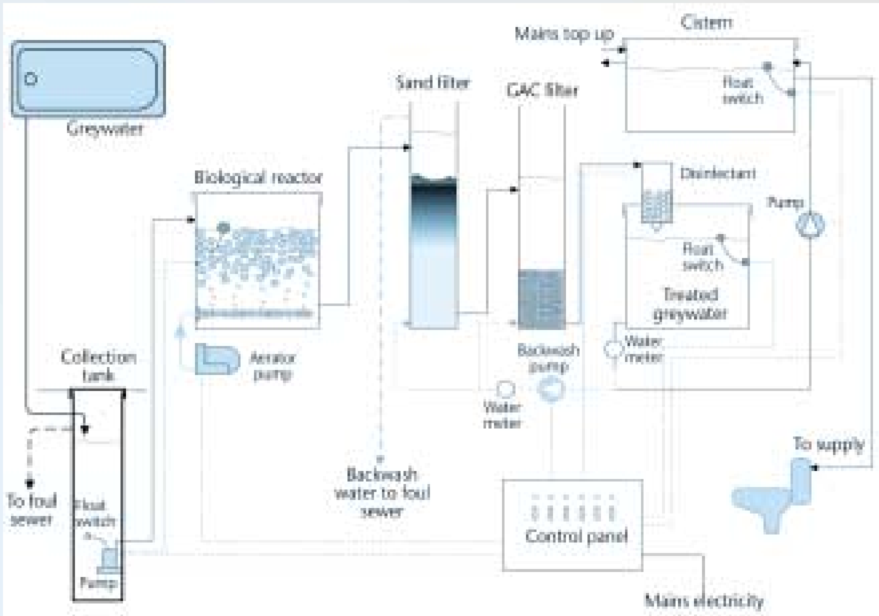
They are two basic types of heat pump: water-to-air and water-to-water units, depending on whether the heat distribution system uses air or water. Ground-source heat pumps take energy stored in the ground, which is stable year-round below a certain depth. The normal increase in the earth's temperature is between 1.5°C and 4.5°C per 100 metres, or an average energy flow of 60 mW/m^2.

This heat energy for the heat pump can be extracted through a closed or open-circuit borehole. Closed loops generally rely on the latent heat of the surrounding rock, into which heat-exchange pipework, filled with a water/antifreeze solution, typically descends through 15-180 metres before returning to the heat pump. Horizontal networks are also possible, either by distributing pipework through shallow trenches or by laying them out in mudflats or marshes. Inevitably, the thermal performance of the system will be affected by the closeness of the pipework to the surface and by the influence of solar gains and rainfall evaporation.

Open-loop circuits generally involve the extraction of groundwater, either from permeable rocks or an aquifer. The water is extracted by a submersible pump, passed through a heat exchanger in an air-handling unit where the heat is released (or absorbed, depending on mode of operation) and then either returned to a second borehole or dumped to a drain. Given suitable treatment, this water can also be used for toilet flushing or irrigation, which may itself justify an open-circuit solution.

The big drawback with open-loop systems is their inability to cope with high heating or cooling loads. Boreholes can be expensive to sink. As several boreholes may be needed to meet a desired output, capital and maintenance costs can be prohibitive. Open-loop systems can also be difficult to maintain. It is not easy to pressurize the ground to accept return water. Users may have to contend with algal growth and the settling out of suspended solids, all of which can block up a borehole.

Figure 1
Schematic of a greywater treatment system, suitable for a large-scale project



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Water conservation

The increasing demand for potable water supplies has put the focus on more efficient use of drinking water, and on ways the wastewater and rainwater can be recovered and used for non-potable purposes such as toilet flushing, site irrigation and makeup water for steam boilers. In countries where drought is an ever-present danger, such systems may be a solution to unreliable water supplies.

Rainwater can be used for drinking purposes once suitable treatment has been applied, such as UV disinfection. The system can be very simple, involving little more than gutters, storage cisterns and suitable pipework. On the downside, the system is dependent on the degree and periodicity of rainfall, and sufficient storage must be provided to sustain the building community, particularly if there is no mains water connection.

Wastewater systems (also termed greywater systems) are more complicated (Figure 1). This involves the collection and storage of wastewater from baths, showers and domestic appliances. The supply of greywater is not dependent on rainfall, so savings can be made even in times of drought.

Whereas disinfection is not necessary for rainwater systems used in toilet flushing, a disinfection system is vital for greywater systems as the proliferation of harmful bacteria can pose a health hazard. Greywater systems require periodic topping up of disinfectant and the cleaning and replacement of filters.

While such technology may appear eminently suitable for use in developing countries (particularly where potable water is in short supply, or in arid regions for landscape irrigation), the emphasis is on maintenance and operation.

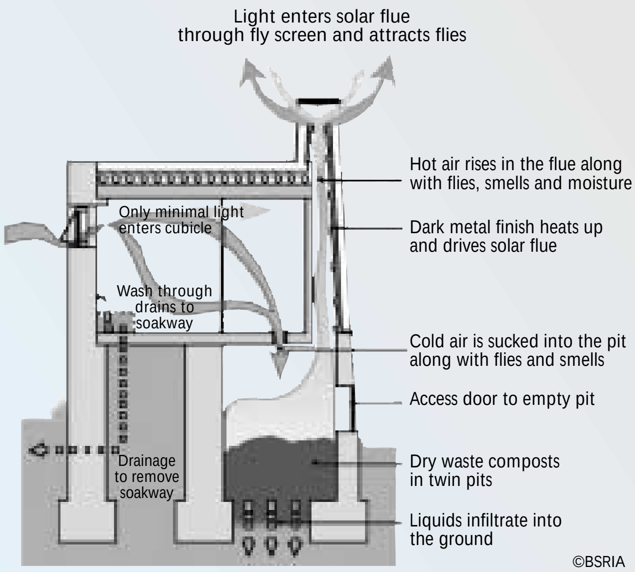
Water supply is only one side of the water conservation equation. The other major problem for buildings in developing countries is lack of a sanitation infrastructure. If there is no sewerage system, then designers need to find an alternative method to dispose of human effluent.

Composting toilets are one such mechanism (Figure 2). They are simple to construct, using either prefabricated components or natural materials on site. They have few moving parts and are fairly maintenance-free. What little maintenance is needed can be carried out with minimal training and the simplest of tools.

Most composting toilets work in the same way: waste is deposited in a chamber directly below the toilet bowl, where it can be allowed to break down by a process of mixing, aeration and warming. Wood shavings are a suitable absorbant. After about a year the composted material can be safely disposed of, or used as local fertilizer – though not on crops.

Drawbacks are few: some systems need electric heat to accelerate the biological activity, others use a stirring prong to maintain aerobic conditions. Some systems, typically vault composters, rely on a colony of worms to hasten the composting process. Only a litre of water is needed pre-flush, and this can easily come from a greywater or rainwater system.[6]

Figure 2
Operating principle of a composting toilet



Conclusions

Clearly, there are no panaceas when it comes to identifying best-fit building services solutions for developing countries. Some approaches are best left well alone (Table 1), particularly if a proposed system can be fragile in operation. Complex services and controls require excellence in their management, and this may be in short supply in resource-strapped regions of the world.

The myth of building intelligence is that it is *fit-and-forget*, and that electronics will do the rest. The truth is that many building services systems are *fit-and-manage*, and problems will always occur where complex technology is applied in a context that is deficient in skilled facilities management.[7] Simpler, more robust solutions are more suitable for these contexts, even if the theoretical energy savings would be less than optimal.

Is it possible that controlled application of best-fit technologies in developing countries will drive reductions in emissions of greenhouse gases? If the design practices typified by the Harare International School can be replicated on a regular basis, then there is every hope that they will. However, it is sobering to note that there's one thing developing nations want, and that is to become developed nations. Evidence suggests that their inspiration often comes not from the best that environmentally sustainable architecture can offer, but from what developed nations themselves clearly prize: ostentatious architectural symbols of wealth and prosperity. That tends to manifest itself through externally mounted building services and 100% glazed facades – facing south.

It matters not whether these buildings are the preposterous consequence of talented designers making their names by proposing fundamentally flawed designs, and then making them work through technical skill and panache. They are desired symbols of national economic prosperity that do not go unnoticed by emerging economies.

Western design communities need to recognize the risks in what they do at home, and try harder to acquaint themselves with a good knowledge of the properties of materials, embodied energy and

The open building concept for an adaptable built environment

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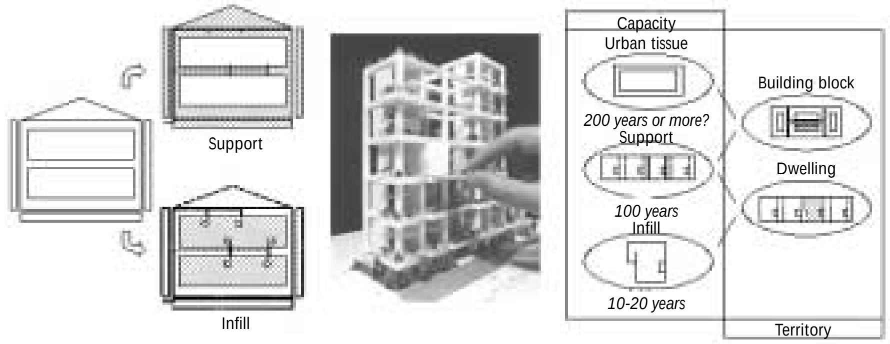
The open building (OB) approach facilitates systematization of the built environment as a set of distinctly layered sub-systems. One sub-system can be replaced by various alternatives without disturbing other sub-systems. The exchangeable nature of sub-systems makes it feasible to customize a building according to the stakeholders' specific requirements, and to adapt to requirements that are constantly changing.

This concept is applicable to the efficient regeneration of existing buildings, as well as to the realization of "upgradeable buildings" and "partnership-based growing buildings". By continuously improving serviceability and resource productivity, the open building approach improves a building's sustainability.

Figure 1
Subdivision of the built environment into distinct levels



A building is a complicated assembly of various elements that embody the complicated relationship among its stakeholders. To be serviceable over time, a building needs to meet (at acceptable levels) the ever changing, unique requirements of its stakeholders. However, physical complicatedness and socio-economic entanglement can be obstructive factors with respect to customization according to individual stakeholder requirements and adaptation to the ever changing requirements of the building.

The open building approach can be the solution to problems related to complicatedness and entanglement. It is a method of subdividing the built environment into clearly distinct levels, which are made up of functional or spatial groups of elements (Figure 1). Using the approach applied in the Netherlands, Japan and Finland, these levels may be referred to as "urban tissue", "support" and "infill". In the United States they may be referred to as the "base building" and "fit-outs".[1,2]

Levels correspond to specific stakeholders. In the case of housing, "infill" corresponds to residents of dwelling units and "support" to owners and leaseholders. Buildings that do not have distinct levels tend to entangle decision making by stakeholders. However, the open building approach enables

Open building is an innovative way to produce – and renovate – neighbourhoods and buildings, using the latest building technology, information management and construction logistics. Open building projects are based on certain principles. The most basic of these is the designation of "levels": decisions and physical parts are grouped according to whether they belong to the level of urban fabric/tissue (the building site), the base building or support (the structural envelope), fit-out or infill (interior partitions, etc.) or FF&E (furnishings, fixtures and equipment).

This approach enhances the efficiency of the building process while increasing the variety, flexibility and quality of the building itself.

In large projects (either new construction or major renovation) the application of open building principles means that uniform unit designs are no more difficult to install than interior layouts. Thus, there is a better balance between supply and demand and less need for rework. Buildings and urban fabric remain valuable well into the future because they are planned for change as well as stability.

In normal construction, mechanical equipment infrastructure systems are completely intertwined. Structures and partitions belong to different parties (in the legal and trade jurisdiction sense). Entanglement leads to disputes, higher initial and long-term costs, reduced quality and confusing regulations. It also obstructs system upgrades and spatial reconfiguration.

In open building, while each level may include parts of several technical systems (e.g. fit-out may include partitions, electrical, plumbing, mechanical, fixtures and cabinets) the physical systems that comprise a level are delivered as a distinct "bundle". Open building disentangles building systems by reducing sub-system dependencies (therefore reducing conflicts among the various parties) and organizes parts according to their life span, leading to more sustainable buildings and neighbourhoods. Environments that achieve sustainability do so in part because they can adjust with reduced waste and disruption.

Under open building principles, an urban design enables a variety of buildings to be erected and replaced without altering the basic urban patterns of space and infrastructure. A base building with parts shared by all occupants enables freedom of layout at the level of the individual unit; a fixed arrangement of walls and doors enables a certain variety of furniture arrangements.

This approach ensures that as buildings and neighbourhoods are constructed and altered, each "social unit" (e.g. neighbourhood council, condominium association, individual occupant) is assured a clear measure of both freedom and responsibility. Another important principle of open building is that users/inhabitants make design decisions; more generally, design is a process with multiple participants, including various kinds of professionals.

Adapted from CIB leaflet on open building (www.decco.nl/obi/obi_flye.htm).

the environmental benefits of robust energy conservation measures. With that knowledge they can educate clients and governments on both sides of the economic divide on the most sustainable way to move forward the practice of true low-energy building design.

Notes

1. *Our energy future – creating a low carbon economy*, DTI Energy White Paper, 2003.
2. PROBE: Post-occupancy Review of Buildings and their Engineering, 1995-2002 (a research project managed by Roderic Bunn, former editor of *Building Services Journal*, for the DTI under the Partners In Innovation collaborative research programme).
3. Barnard, N. (1994) *Dynamic energy storage in the building fabric*. BSRIA TR 9/94. ISBN 0 86022 372 8.
4. Ibid.
5. Rawlings, R. (1999) *Ground-source heat pumps*. BSRIA TN 18/99. ISBN 0 86022 506 2.
6. Brewer, D., R. Brown and G. Stanfield (2001) *Rainwater and greywater in buildings*. BSRIA TN 7/2001. ISBN 0 86022 577 1.
7. Barnard (op.cit.).

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autonomous decision making at each level without the entanglement of different interests. For example, where this approach is applied to housing, the residents of dwelling units (i.e. stakeholders of "infill") can arrange interiors independently if the arrangement does not expand beyond the defined boundaries between "infill" and "support".

The potential for autonomy and disentanglement increases the economic and technical feasibility of customization according to stakeholders' unique requirements by:

- inducing various forms of participation in the design process by users, residents and different types of professionals;
- managing the "buy to order" or "make to order" supply chain of each stakeholder at reasonable cost.

Thus the open building approach can promote various arrangements of "fit-outs" within the framework of a "base building", respecting the identities of the building's users and residents.

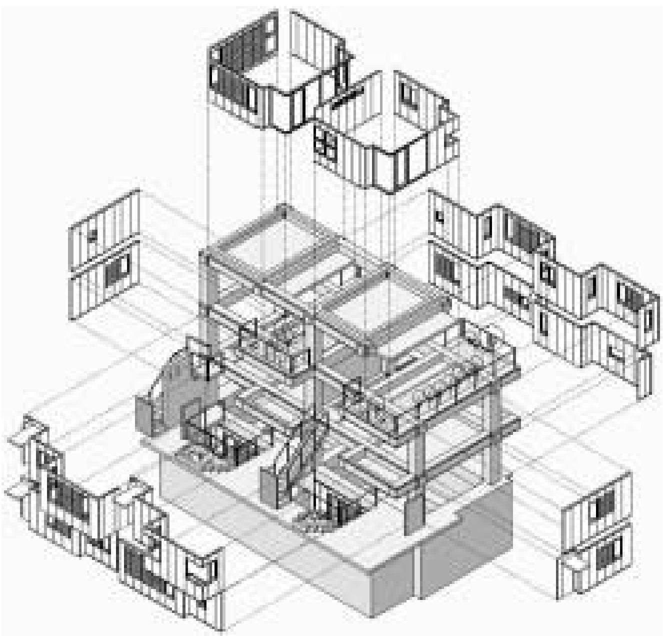
Based on a number of case studies concerned with changes in buildings over time, Stewart Brand has illustrated the concept of "shearing layers of change" regarding components' different rates of change. These layers are called "site", "skin", "structure", "services", "space plan" and "stuff".[3] The "shearing layers of change" concept suggests how distinct subdivision could enhance continual adaptation through re- placement of groups of elements. Distinct subdivision into functional or spatial groups of elements with sophisticated interfaces, using the open building approach, is a form of "shearing layers of change" (to use Brand's term). It allows replacement of a group of elements with another group that performs the same or a more suitable function. The open building approach therefore facilitates efficient adaptation to changing contexts over time, including:

- adjustability to unpredictable changes in a socio-economic context;
- upgradeability in order to profit from future innovation.

The open building approach has the potential to improve buildings' sustainability in both developed and developing countries.

Figure 2
The open building approach can generate mechanisms for continuous transformation

Figure 3
Upgradeable buildings can respond to innovation



Potential of OB in developed countries: refurbishment of existing buildings

In most developed countries, quantitative demand for floor space in buildings is limited by the fact that populations are declining or only slowly increasing. However, qualitative demand for built environment is influenced by ongoing economic and social transformations. Considering the magnitude of resource use for construction related activities in developed countries, it is essential to avoid repetition of demolish-and-new-build as a method of adapting to qualitative demand. The open building approach could be an alternative, systematized and efficient method of refurbishment to adapt existing buildings to changing qualitative demand through continual replacement of "infill" or "fit-outs".

In both western and eastern Europe there are examples of run-down housing estates being regenerated, using an open building approach that combines:

- rehabilitation of "supports" by landlords and of "urban tissue" by local authorities, including improvement of energy efficiency, amenities and capacity for change;

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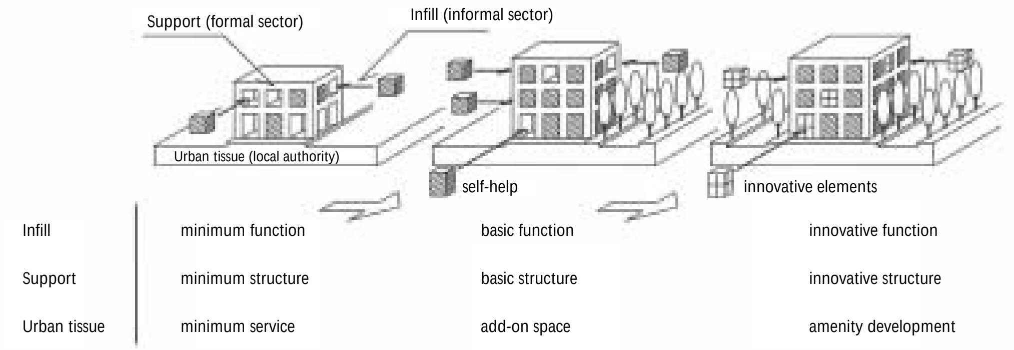
- promotion of the refitting of dwelling units through encouraging various forms of resident commitment.

These examples demonstrate that the open building approach can improve the sustainability of housing estates by generating a self-governing mechanism for continual transformation to maintain serviceability under partnerships of stakeholders (Figure 2).

Figure 4
A partnership-based growing building



Potential of OB in developing countries: upgradeable buildings

Today's innovative technology could soon be out of date. If buildings are to be serviceable in a period of rapid innovation, they need to be upgradeable. A large number of new buildings are being constructed in developed and developing countries, reflecting economic growth. However, because of pressure to achieve rapid construction at minimum cost, some new buildings embody an entangled combination of elements that could obstruct upgrading of buildings. This means many buildings with poor energy efficiency and considerable environmental impacts that are being constructed in developing countries risk technological deterioration in the future. If the demolish-and-new-build method were used as an alternative to deterioration, or if these buildings continued their poor environmental performance, this could result in a global sustainability crisis due to huge resource and energy use, waste generation and environmental impacts. To mitigate the probable risk, it is essential to introduce the concept of "upgradeable buildings" (based on the open building approach) in developing countries. "Upgradeable buildings" can be used for a longer period by inducing innovation over time.[4]

Japan has experienced the problems associated with less-upgradeable buildings in a period of rapid economic growth. There are several challenging examples of construction of upgradeable buildings in Japan (Figure 2 and Figure 3).

Potential of OB in developing countries: partnership-based growing buildings

In megacities in developing countries, informal construction activities play a considerable role in providing shelter to meet basic human needs. However, in many megacities the role of the informal sector is underestimated by the formal sector. Eventually, investments by the formal and informal sectors are fragmented despite the limited resources available for investment. To utilize limited resources efficiently, the "partnership-based growing building" concept (based on the open building approach) needs to be introduced in order to supply quality shelter for as many people as possible. Within the framework of a partnership-based growing building (Figure 4) the formal sector focuses investments on the "urban tissue" and "support" level, while the informal sector is responsible for installing "infill" through utilizing self-help activities. Because of the adaptable nature of the open building approach, a partnership-based growing building can replace or add "infill" and some "supports" and "urban tissue" in the future, responding to socio-economic changes and innovation. This approach gives people hope by demonstrating the "growing" of a building through a transparent process.

Concluding comments: probable dematerialization using the open building approach

The open building approach has the potential to enhance customization and continuous adaptation over time in different contexts in both developed and developing countries. As this approach is disseminated, buildings' serviceability increases their economic value. Especially at the "infill" level, it is probable that an infill supplier could be a service rather than a product provider. Based on the open building approach, the author and industrial partners are currently trying to develop and disseminate a new business model in which infill is leased as movable property (Figure 5).[5] This suggests that the open building approach facilitates an emphasis on the value of serviceability, which promotes the dematerialization of building related economic activities. The open building approach can improve the sustainability of buildings not only through technological, social and economic disentanglement, but also through dematerialization.

Notes

1. Habraken, John (2000) *Supports: An alternate to mass housing*. Urban International Press (reprint of 1972 English edition).
2. Kendall, Stephen and Jonathan Teicher (2000) *Residential Open Building*. Spon, London and New York.
3. Brand, Stewart (1994) *How Buildings Learn: What Happens After They're Built*. Viking, New York.
4. www.habraken.com/john/open.htm.
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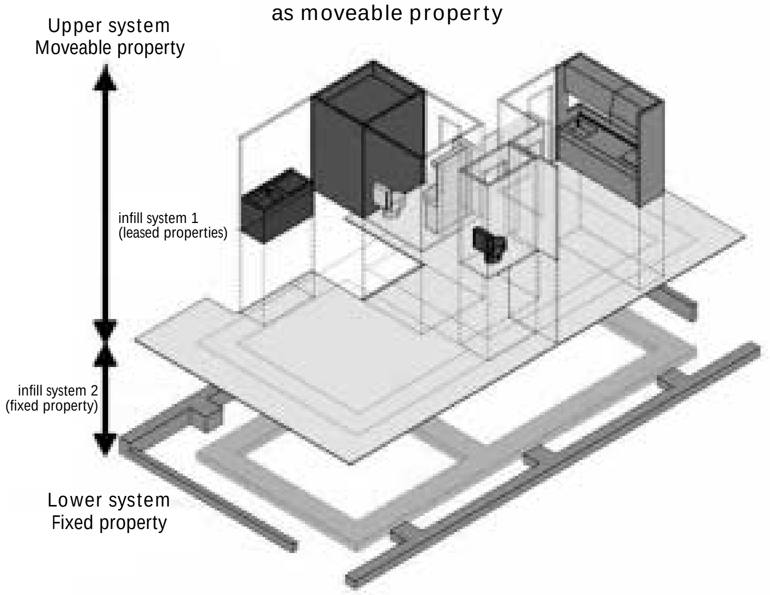
Figure 5
Infill could be leased as moveable property



Concepts and instruments for a sustainable construction sector

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Summary

This article presents an overview of methods used by the Wuppertal Institute to determine sustainability targets in the construction sector and to develop pathways for achieving targeted improvements. Resource productivity is considered over a building's entire life cycle (MIPS). The COMPASS concept integrates environmental, economic and social aspects for single companies or industrial sectors in order to make progress towards greater sustainability. Profiting from each of these approaches, and based on various types of research, recommendations are derived for companies and policy makers. Multi-stakeholder processes can be used to promote overall sustainable development in the construction sector, and eventually to integrate concepts related specifically to the micro and meso levels.

Résumé

L'article examine les méthodes employées par le Wuppertal Institute pour fixer des objectifs de durabilité dans le secteur du bâtiment et élaborer les filières qui permettront les améliorations recherchées. La productivité des ressources est étudiée sur la totalité du cycle de vie du bâtiment. Le concept de COMPASS intègre les aspects environnementaux, économiques et sociaux pour des entreprises isolées ou des secteurs industriels entiers, afin de progresser vers une plus grande durabilité. Tirant parti de chacune de ces approches et des divers travaux de recherche engagés, des recommandations sont formulées à l'intention des entreprises et des décideurs. Des processus associant de nombreux acteurs peuvent être mis en place pour promouvoir le développement durable dans l'ensemble du secteur du bâtiment, voire pour intégrer des concepts spécifiques aux niveaux microsectoriels et mésosectoriels.

Resumen

El artículo presenta una visión general de los métodos del Instituto Wuppertal para definir objetivos sostenibles en el sector de la construcción y para desarrollar procedimientos que permitirán lograr las mejoras deseadas. Se estudia la productividad de recursos durante todo el ciclo de vida de un edificio (MIPS). El concepto COMPASS integra aspectos medioambientales, económicos y sociales para compañías individuales o sectores industriales con miras a progresar hacia una mayor sostenibilidad. Aprovechando cada uno de estos enfoques y basándose en varios tipos de investigación, se preparan recomendaciones para las compañías y los encargados de elaborar las políticas. Procesos que cuentan con la participación de múltiples partes interesadas pueden ser utilizados para promover el desarrollo sostenible en general en el sector de la construcción y, con el tiempo, integrar conceptos relacionados específicamente con niveles medianos y pequeños.

Sustainable development has been an internationally recognized aim since the UN Conference on Environment and Development in Rio de Janeiro in 1992. Its central challenges are the maintenance of social security and justice, sustainable economic development, and the preservation and creation of an intact environment. Looking at industrial sectors, the construction sector is of particular importance. On one hand, it makes a vital contribution to the social and economic development of every country by providing housing and infrastructure; on the other, this sector is an important consumer of non-renewable resources, a substantial source of waste, a polluter of air and water, and an important contributor to land dereliction. Material flows analyses for Germany, Japan and the United States show that the construction sector accounts for between one-third and one-half of commodity flows when expressed in terms of weight (Figure 1).[1]

Setting the target

In many cases buildings are harmful to workers during the construction period, as well as to occupants due to unhealthy air and indoor climate. Longer-term environmental impacts also result from buildings' use and maintenance. In Germany about one-third of total primary energy is used just to maintain existing structures and keep them running. Moreover, demolition generates enormous amounts of waste to be deposed of.

A core instrument for determining the *environmental* impact of materials in the construction industry is the "ecological rucksack", which describes the total quantity of material that must be extracted to obtain a unit of pure (and thus usable) material. For example, for iron ore extraction the ecological rucksack can be expressed as a ratio of 14:1 – that is, 14 metric tonnes of waste in the form of tailings or mine waste are created in the production of one metric tonne of iron. In the case of rarer materials such as gold and platinum, the ratio can range up to 350,000:1.

With their knowledge of these impacts and the extent of material consumption in today's societies, senior governmental, non-governmental, industry and academic leaders argue the following: to redirect our course towards that of a sustainable economy, each country's total resource productivity should be increased by a factor of 2; and in industrialized countries it should be increased by a factor of 4 within the next decade and by a factor of 10 overall within one generation. To achieve these increases, every actor within the economy must optimize resource use from the national (macro) level, through the sectoral and regional (meso) levels and on down to the single firm and household level (micro) levels.

Different tools have been developed to measure resource productivity and the potential for improvement. These tools can be applied to the construction sector. A sustainable construction sector also has to consider other dimensions (e.g. economic and social considerations) in order to take the holistic approach needed to build a sustainable future.

From resource management towards a sustainable construction sector

"Only what is measured gets done" is often the underlying principle of the factor X discussion. The method we use to measure resource productivity depends on the extent of information (unit) we desire. For information based on mass units, we chose MIPS (Material Input per Service Unit), and for mass and monetary units combined with social considerations we chose COMPASS (Companies' and Sectors' Path to Sustainability). The different methods will be briefly explained below to show which periods in a building's life cycle offer potential for improvement within the fixed targets.

MIPS: a monitoring tool for material flows

MIPS is a methodology for measuring material input at the level of products, including all their "ecological rucksacks" – that is, the total mass of material flows activated by an item of consumption in the course of its life cycle (www.wupperinst. org).[2] MIPS is computed in material input per total unit of services delivered by the product over its entire useful life span Resource extraction, manufacturing, transport, packaging, operation, reuse, recycling and remanufacturing are accounted for, as well as final waste disposal.[3] The total MI carried by a finished product the product's ecological rucksack.

The S in the MIPS formula (Figure 2) stands for the total number of units of service (utility) delivered by the product during its lifetime, or the expected total number of service units that the product might supply during its lifetime (in the MIPS concept, products are "service deliver machines"). The S number is usually greater than that implied by product warranties.

Resource productivity can thus be improved by lowering MI for a given S, or by increasing S with a fixed quantity of resources. Either can be achieved through technological or managerial/societal changes/innovations.

What does this mean for the actual construction site?

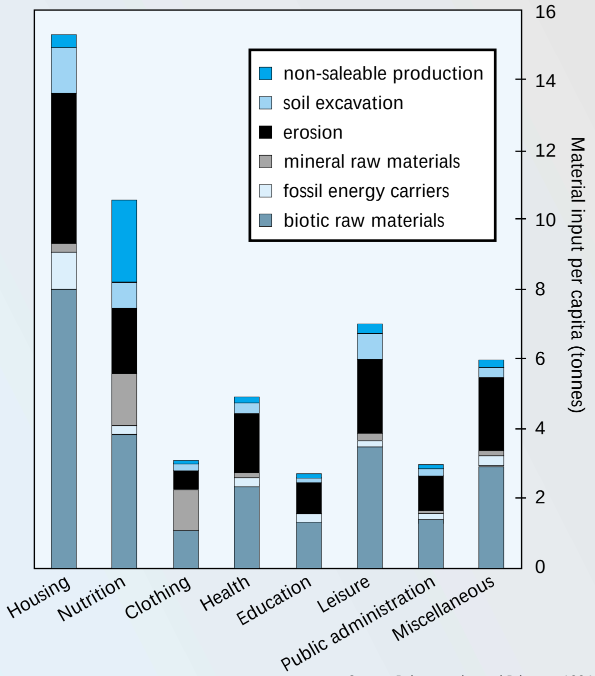
For eight years the Wuppertal Institute has been working in the field of resource efficient building and construction (www.mipshaus. de). Having analyzed and assessed over 100 buildings of various sizes using the MIPS concept, we have been able to show that, in terms of resources, the relevance of various life-cycle phases differs greatly between new and existing buildings (see next section). Unlike existing buildings, new buildings show a relatively small importance of the "use phase". For example, a pair of new semi-detached houses in the ecological settlement of Flintenbreite have a TMR (total material requirement) of 122 kg/m[2] per year. As shown in Figure 3, the renovation and construction phases dominate the entire life cycle in terms of material requirements. The enormous relevance of the renovation process in this case results in particular from the aluminium roof, which will have to be replaced twice (according to German statistics) during the calculated life expectancy of 80 years.

Consequently, in order to achieve an improved MIPS value, true dematerialization must focus on virgin resource extraction and not just intensity of use. The environmental impacts of the technologies and substitutions that lead to dematerialization therefore need to be scrutinized carefully. Dematerialization must also focus on a shift to reuse, recycling and remanufacturing – in short, all the important aspects of closing materials loops. Additionally, de-energization, decarbonization and detoxification of the industrial system should accompany dematerialization if significant resource and environmental benefits are to be achieved. Further dematerialization can be achieved through technological progress. Summarizing the potential for improving the environmental sustainability of buildings, Stefan Bringezu suggests what he calls the "Golden Rules of Eco-Design":[4]

1. Potential impacts on the environment should be considered on a life cycle-wide basis.
2. Intensity of use of processes, products and services should be maximized.
3. Intensity of resource use (material, energy and land) should be minimized.
4. Hazardous substances should be eliminated.
5. Resource inputs should be shifted towards renewables.

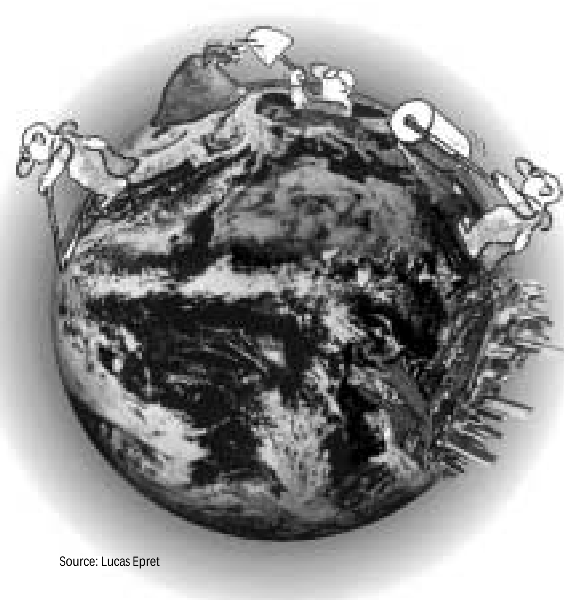
How these suggestions could be implemented in practice by enterprises in the construction sector is illustrated in Table 1.

Figure 1
Material input per capita for different types of needs in western Germany, 1990



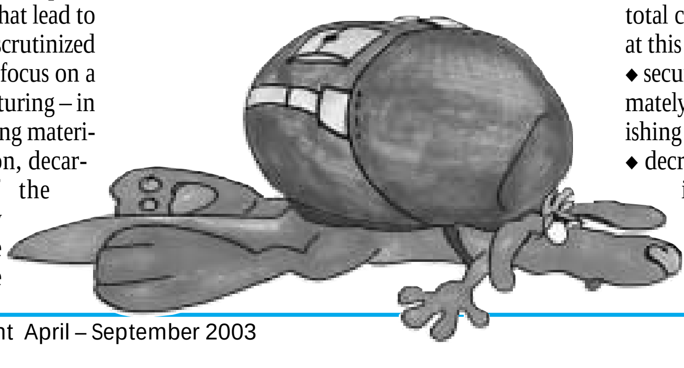
Source: Behrensmeier und Bringezu 1994

Natural resources are the basis of life – today and for future generations



Source: Lucas Epret

The ecological rucksack of some products or services is too heavy



Building renovation: a chance for climate protection and the labour market

Having shown how resource productivity and environmental sustainability in the construction of new buildings can be improved, it is important to consider the contribution of existing buildings to meeting sustainability targets. In this case, the "use phase" is of crucial importance because of the current high energy demand for heating, with around 200 kWh/m[2] per year or 20 litres of oil/m[2]/year. In a study called "The Renovation of a Building – A Chance for Climate Protection and the Labour Market" we have investigated the possible effects on the environment, and on the labour market in the construction sector, of the extensive renovation of residential buildings to optimize energy savings. The starting point was the joint project "Das Plus für Arbeit und Umwelt", which the industrial union Bauen-Agrar-Umwelt (IG BAU) and Greenpeace intend to initiate in cooperation with the housing industry (www.arbeit-und-umwelt.de).

The assumption underlying the study is that through this initiative and additional measures (such as incentives, above all on the part of the federal government), the number of residential buildings to be renovated to introduce energy-saving measures could be increased from around 150,000 today to approximately 330,000 per year To achieve this, around DM 15 billion (approximately Euro 7.65 billion) would have to be invested annually between 1999 and 2020. This sum corresponds to almost 3% of total construction volume in 1997. Investments at this level would:

- secure and create on a long-term basis approximately 430,000 jobs (174,000 of these in the finishing trade alone);
- decrease energy costs by reducing final energy input by 1111 PJ (50%) and avoid up to 97.5 million tonnes (58%) of CO_2 compared with 1999, the reference year;
- achieve considerable resource savings

(balance of expended and saved material flows), which will reach a scale of around 68 million metric tonnes per year by 2020.

This investment plan, which is now activated by a governmental support programme (www.kfw.de) among other measures, will entail higher state revenues from national insurance and from direct and indirect taxes. At the same time, expenditure for social benefits will decrease because of an improvement in the labour market situation.

Comparing the potential of existing and new buildings, we can conclude that on the German and similar European markets the (energy related) renovation of existing buildings offers a far more promising contribution to sustainable construction than construction of new ones. Furthermore, economic and social benefits as well as land savings should lead us to direct our efforts towards the modernization of existing buildings. It goes without saying that where new construction is necessary, the utmost resource productivity and eco-efficiency must be targeted.

COMPASS: the path to sustainability for companies and sectors

It is important for companies and sectors to know what kind of targets and actions will lead them towards sustainability. Resource productivity is only one important path; in the broader context of sustainable development there are also numerous other economic targets (e.g. high profits, high competitiveness, low rate of investment payback), environmental targets (e.g. low toxicity, high biodiversity, low erosion) and social targets (e.g. employee satisfaction over low unemployment rate, overall stability in society) that have to be addressed.

COMPASS (Companies' and Sectors' Path to Sustainability)[5] is a tool developed to provide decision makers in a company or a sector with sufficient information for integrated analysis and decisions. It includes a methodological framework, instruments and measures to put the normative concept of sustainable development into practice. Step by step, it helps the user understand what sustainable development means for an enterprise or a sector – from a life-cycle perspective of a product or service – and shows the extent to which a development in the direction of a sustainable economy has already been achieved.

In cooperation with a company in the housing industry, the sustainability of its product range (four residential houses) was investigated. Economic and environmental issues were the main focus.[6] However, it was important to record acceptance by tenants or buyers of the houses being offered. Product specific indicators apart from MIPS were determined in dialogues with people involved in the COMPASS assessment. The products in question were detached houses of varied design, appealing mostly to the same type of prospective buyers. The resulting indicators considered by the company are:

- resource consumption (production and use);
- energy consumption;
- reduction of costs;
- effects on man;
- effects on the ecosystem;
- acceptance by tenants;
- profitability.

All indicators will be applied to the service unit "living space and year". Only the "acceptance" indicator will be assessed per tenant or buyer questioned. Taking the "resource productivity" indicator as an example, the structure and procedure are briefly explained. The "system-wide resource consumption" indicator can be subdivided into part indicators (Figure 4). The subdivision into part and sub-indicators, for example, depends on production processes and responsibilities within companies.

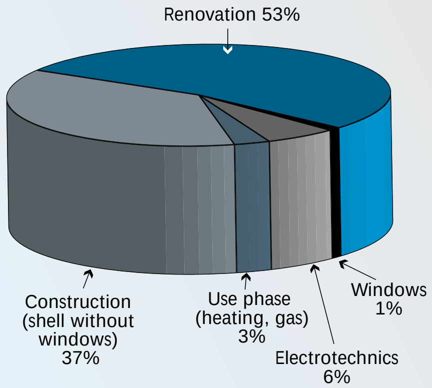
An assessment scale (performance comparison) for all indicators was determined, ranging from 1 (very good) to 6 (unsatisfactory). Grade 4 (satisfactory) corresponds to the state of the art. With the help of "traffic lights" – grades 5 and 6 (red), grades 2, 3 and 4 (amber) and grade 1 (green) – the management decisions or measures introduced can be observed, discussed and evaluated with respect to their effects at all indicator levels. The grades will then be equally weighted from the bottom up and identified as the arithmetical mean of the overall grade of the indicator at the next higher level. The grading system can, of course, be freely chosen and can be shown in the standards of other countries.

To compare the houses of the company mentioned above, results were clearly presented on the topmost indicator level as in Figure 5. In the so-called "Sustainable Development Radar" (COMPASS$_{radar}$) the economic, environmental and social efforts of entrepreneurial development are portrayed. The axes show the selected indicators whereby the determined grades describe the distance to the defined target (grade 1) and the state of the art (grade 4).

Figure 2
The MIPS formula

$$MIPS = \frac{MI}{S}$$

Figure 3
Resource intensity of the new Flintenbreite Housing Estate in Lübeck, Germany



Source: Holger Wallbaum, *Denk- und Kommunikationsansätze zur Bewertung des nachhaltigen Bauens und Wohnens*. Dissertation, Fachbereich Architektur, University of Hannover, 2002. (Also see www.flintenbreite.de.)

The "Cement and Sustainability" initiative

It is widely recognized that to achieve sustainable development, it is essential for different actors to work together. The federation of the German Cement Industry (Bundesverband der Deutschen Zementindustrie, BDZ) and the industrial union for the building and construction industry (IG BAU) have concluded a sectoral agreement to facilitate joint consideration of economic, ecological and social challenges throughout the whole life cycle of cement products. Based on stakeholder dialogue and practical projects, this initiative tackles the issues of biodiversity, protection of resources, sustainable transport and logistics, as well as workers' qualifications. The stakes in the cement industry are particularly high due to large capital investments and long amortization periods in an increasingly globalized market.

Table 1
Eco-efficiency strategies in the construction sector

Level of product components	Level of product structure
Selection of materials with little environmental impact, e.g. • environmentally compatible materials (small ecological rucksack, no substances toxic to humans or the environment) • renewable materials (if sustainably produced) • materials with low energy content • recycled materials • recyclable materials	Optimization of product techniques, e.g. • alternative product processes • more efficient energy use • less product waste
Reduction of material inputs, e.g. • reduction of product weight • reduction of product volume	Optimization of distribution systems, e.g. • less, environmentally compatible and reusable packages • use of more energy efficient transport systems • choice of more energy efficient logistics
	Reduction of environmental impacts during use phase, e.g. • more efficient energy use • energy from environmentally compatible sources
Shifting from product-oriented to service-oriented approaches • mobility management, e.g. car sharing, removal services, caretaker services	

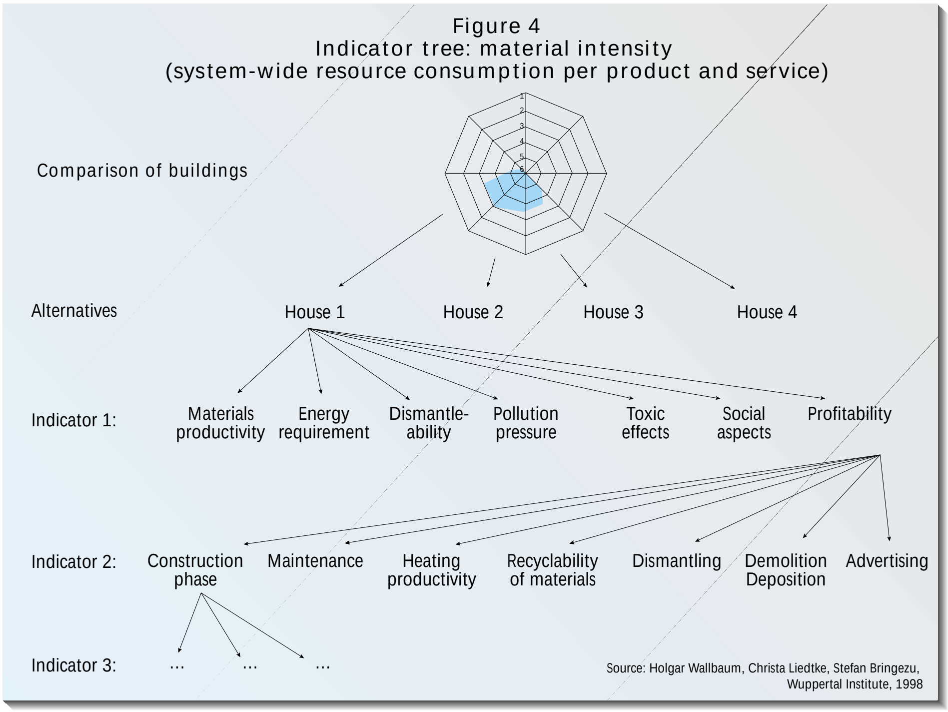


Figure 4
Indicator tree: material intensity
(system-wide resource consumption per product and service)

Source: Holgar Wallbaum, Christa Liedtke, Stefan Bringezu, Wuppertal Institute, 1998

Multi-stakeholder processes as a means of integration

The construction sector involves a multitude of actors and stakeholders, including building material manufacturers, building and construction companies, small and medium-sized enterprises (above all those engaged in trade), unions, planners, environmental NGOs, users, governmental institutions, financial institutions and research institutes. Stakeholder-based approaches are widely seen as a promising way to use on an equal basis the expertise and experience of all those involved and affected. With a view to finding quality sustainable development solutions, such an approach is opposed to the concept of negotiation, which favours the solution proposed by the strongest rather than the best and most sustainable solution.

A recent study from Germany[7] found that the large majority of stakeholders asserted the need for multi-stakeholder cooperation. Many went so far as to state that it represents the only viable solution to avoid misleading incentives and to improve industrial governance. As a result, stakeholder processes can lead to voluntary self-governance or to improved and more informed governance by the state (through incentives or legislation).

However, this approach also gives rise to considerable criticism and scepticism. Critics mostly refer to these processes as merely serving as an alibi for political inertia. Furthermore, they fear that solutions will be limited to the lowest common denominator among the actors involved instead of leading a big step towards sustainable development. The constraints can be found in the organizations themselves, the relationships between the different actors, and general considerations such as the sector's economic situation.

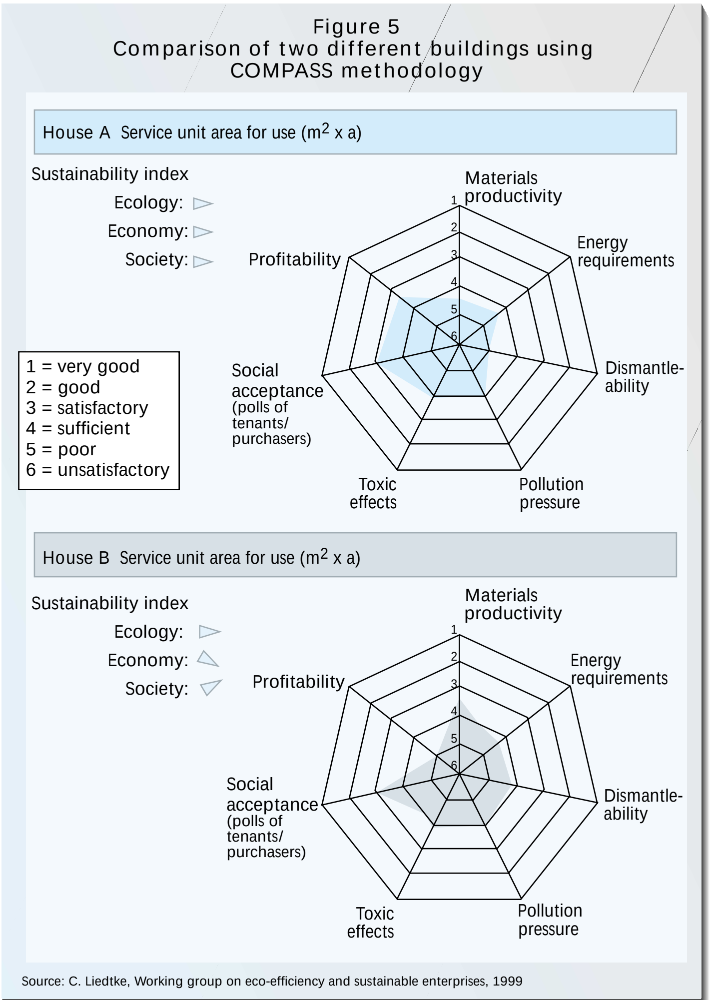


Figure 5
Comparison of two different buildings using COMPASS methodology

Source: C. Liedtke, Working group on eco-efficiency and sustainable enterprises, 1999

As for the organizations seen as collective actors, it is important to note their specific logic and functioning. Most serve specific aims in the first place and find it hard to justify any slightly differentiating position to their members. This is especially true for the federations of the German construction industry concerned with overcoming the grave economic crisis, and for unions concerned with the preservation of jobs and fair working conditions in times of economic recession. In addition, a long tradition of corporatism in Germany has produced well-established relationships and modes of negotiation that are difficult to change.

In examining the commitment of business in stakeholder processes, we must identify the difference between the construction industry itself and producers of building material. The first, represented by its federations, shows very little commitment to sustainability issues, which is explained by the fact that firms only carry out decisions taken by others. The latter are exposed to much higher pressure from civil society because of their direct access to resources. This is directly noticeable by neighbours and concerned citizens. As a result, we can observe increasing readiness to cooperate by manufacturers of building materials, as seen in the BDZ/IG BAU initiative at the national level as well as the World Business Council for Sustainable Development (WBCSD) "Cement and Sustainability" initiative.

These examples and others show that rather than abandoning multi-stakeholder processes before they have even started to work efficiently, we should seek to explain the constraints and try to find ways to improve their performance. In particular, power relations between actors and stakeholders and the perception of indivisible problems are main fields for further investigation.

Simultaneous action at different levels

The old saying that too many cooks spoil the broth is certainly not the right approach to creating a sustainable construction sector. The call for simultaneous action at different levels can only be repeated as a conclusion to this article. Necessary coordination through a broadly accepted framework could be established in national and regional multi-stakeholder processes. This, along with the COMPASS methodology, also seems a suitable approach to push forward integration of the core dimensions of sustainability. In addition to the MIPS concept on the environmental side, and economic indicators, more effort still needs to be put into determining the social dimension of sustainability in order to use the COMPASS indicator set.

Notes

1. Adriaanse, A. et al. (1997) *Resource Flows: The Material Basis of Industrial Economies*. World Resource Institute Washington, D.C.

2. Schmidt-Bleek. F. (1993) Wieviel Umwelt braucht der Mensch? *MIPS – Das Mass für oekologisches Wirtschaften, Birkhaeuser* (English translation: The Fossil Makers – Factor 10 and More). Birkhäuser Verlag, Berlin, Basel and Boston. Also see F. Schmidt-Bleek (1995) Increasing resource productivity on the way to sustainability, *Industry and Environment*, Vol. 18, No. 4, pp. 8-12.

3. Ritthoff, M., H. Rohn and C. Liedtke (2002) MIPS berechnen: Ressourcenproduktivität von Produkten und Dienstleistungen. *Wuppertal Spezial 27* (downloadable at www.wupperinst. org). English translation will soon be available.

4. Bringezu, S. (2001) Construction ecology and metabolism: re-materialization and de-materialization. In: *Construction Ecology and Metabolism: Nature as the Basis for the Built Environment*, C. Kibert, J. Sendzimir, G. Guy (eds.), Spon, London.

5. Kuhndt, M. and C. Liedtke (1999) *COMPASS – Die Methodik*. Wuppertal Institute.

6. At first, social criteria were deliberately kept in the background, mainly because at this point the discussion of social indicators on both the national and international level has not yet reached a level equal to that of the development of environmental and economic indicators.

7. Buerkin, C. (2003) *Multi-Stakeholder-Prozesse als Chance für nachhaltiges Wirtschaften: eine kritische Betrachtung am Beispiel des Bausektors*. Thesis, University of Passau/Wuppertal Institute.

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Construction products and life-cycle thinking

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Summary

Life-cycle concepts, in the context of the building and construction sector, are particularly suited to analysis of building products. Such products play an essential role in increasing the energy efficiency of buildings and contributing to economic prosperity. It has been estimated that the construction sector is responsible for up to half of material resources taken from nature and of total waste generation. To manage and minimize the impacts of construction products, the impacts have to be measured using a life-cycle approach. This article reviews life-cycle concepts and considers recent developments. Materials and sustainable construction, environmental product declarations, embodied energy and differences encountered in the assessment of construction products in the North and South are among the topics addressed.

Résumé

Dans le contexte du bâtiment, les concepts fondés sur le cycle de vie se prêtent particulièrement bien à l'analyse des produits de construction, lesquels jouent un rôle essentiel dans l'amélioration de l'efficacité énergétique des bâtiments et la prospérité économique. On estime que le secteur du bâtiment est responsable de près de la moitié des ressources naturelles consommées et du volume total de déchets produits. Pour gérer et limiter le plus possible les impacts des produits de construction, il faut pouvoir les mesurer selon une méthode fondée sur le cycle de vie. L'article fait le point sur les concepts liés au cycle de vie et sur les tendances récentes dans ce domaine. Matériaux et techniques de construction durables, déclarations de produits respectueux de l'environnement, contenu énergétique et différences entre le Nord et le Sud dans la façon d'évaluer les produits de construction figurent parmi les sujets abordés.

Resumen

Los conceptos de ciclo de vida, en el contexto del sector de la construcción y edificios, resultan particularmente apropiados para los productos de construcción. Estos productos desempeñan un papel capital para el aumento de la eficiencia energética de los edificios y el desarrollo de la prosperidad económica. Según estimados, el sector de la construcción utiliza la mitad de los recursos materiales provenientes de la naturaleza y es responsable de la mitad de todos los desechos generados. Para poder administrar y minimizar el impacto de los productos de construcción, es necesario medir dicho impacto utilizando criterios de ciclo de vida. Los autores examinan conceptos de ciclo de vida y analizan la evolución reciente. Algunos de los temas tratados son: materiales y construcción sostenible, declaraciones de productos ambientales, energía incorporada y diferencias en la evaluación de productos de construcción en el Norte y el Sur.

Construction materials and products are essential to life as we know it – with respect to both buildings and infrastructure. Humans spend around 80% of their time (on average) in some type of building or on roads. Construction products play a major role in improving the energy efficiency of buildings and contributing to economic prosperity.

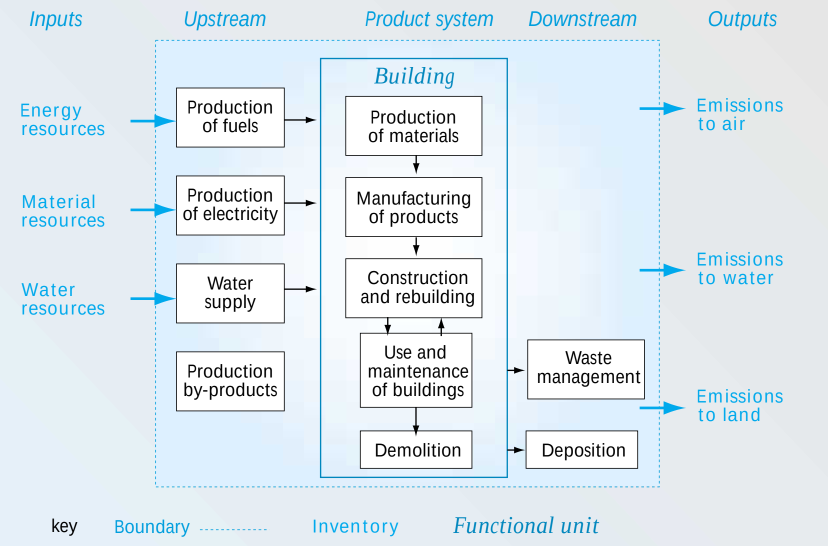
On the other hand, construction products also have a considerable impact on the environment. According to one source, the construction sector is responsible for 50% of the material resources taken from nature and 50% of total waste generated.[1]

The impact of construction products relative to the overall lifetime impact of a building is currently 10-20%. For infrastructure this value is significantly higher, greater than 80% in some cases. As buildings become more energy efficient, the impact of construction products will make up an increasingly significant proportion. This has already been seen in recent entrants for the Green Building Challenge, where construction products contributed up to 50% of the impacts of some of the buildings (www.buildingsgroup.nrcan.gc.ca/projects/gbc_e.html).

Different contexts for considering construction products: North and South

When considering differences related to construction products in the North and South, it is important to make a distinction between "global" and "local" construction. At the most simplistic level, this can be considered as a split between city-based commercial buildings and dwellings, and rural dwellings and public buildings. The distinction can also be applied to products required to

Figure 1
Application of LCA to construction products



create the buildings. There are inherent differences in the nature of materials, the technologies used in extraction and manufacture, and health and safety issues for workers involved in construction product manufacture and construction activities. Global construction products (whether globally traded or locally produced) include cement, steel, aluminium, glass and timber. Local products might include local fired/unfired block, rammed earth, local timber, bamboo, and other renewable products.

Modern building materials can also have a place in local dwellings. The balance must be made between the desirable qualities of indigenous, traditional materials in terms of internal comfort and relatively benign environmental impacts, and the social need for providing quickly constructed, affordable housing solutions on a mass scale. The decision to use different materials will be influenced by a number of factors; for example, *Mbatu* (corrugated sheet) roofs are now commonly used across Africa despite the fact that they offer less protection against extreme temperatures than traditional thatch. To illustrate the complexity of the situation, one of the reasons for this choice is that house owners do not have land rights to grow the thatch material. Clearly the most pressing concern in Southern countries must be the achievement of better living conditions. However, an increasing number of solutions for affordable housing are being imported to the South, often with international funding. Work is urgently needed to understand the social, economic and environmental implications of different products and building solutions. The findings should be fed into national housing strategies and those of the lenders and aid providers, in order to plan ahead and ensure that the best overall solutions are provided.

This article focuses on initiatives related to "global" construction products, as defined above, because this is the area in which the most work has been carried out to date. However, life-cycle thinking has a role in construction at every level. For this reason, many of the concepts discussed are also of relevance to local construction techniques in Southern countries.

Another aspect of international relationships, often overlooked, is information transfer from South to North. Plenty of products with better than average sustainability credentials are already available in the North but remain marginalized: clay reed boards, unfired blocks, hemp lime blocks, and straw or earth buildings to name but a few. A research project on "unburnt clay building products" estimated that these products (bricks, tiles, blocks, boards and plasters) have less than half the environmental impacts of traditional products.[2]

An increase in the use of these products requires investment in research to devise appropriate tests to ensure that they do offer lifetime benefits, as well as a number of significant changes in the tightly defined building regulations, insurance and standards. Influencing these processes is beyond the budgets of most small and medium-sized companies manufacturing these products, which therefore remain outside the mainstream. Occasionally they make a breakthrough. For example, prefabricated straw bale panels were used in a new building for the UK's Bristol University.

Driving demand: sustainable construction

Careful selection of construction products is a feature of national green building labels such as BREEAM in the UK and LEED in the US. These labels provide an easy way for clients to demand more sustainable construction. Using such methods, construction products are treated as more or less important with respect to issues such as energy and water consumption, health considerations, opportunities to use public transport, and facilities for recycling. In turn, they are part of the wider concept of environmental procurement. The International Council for Local Environmental Initiatives (ICLEI) recently published *The World*

Table 1
LCA programmes for construction products worldwide[3]

Country	Programme organizer	LCA schemes for materials and buildings	Year
CH	SIA (Swiss Society of Engineers and Architects)	SIA declaration matrix	1994
D	Stuttgart University	Ganzheitliche Bilanzierung von Baustoffe und Gebäude (LCA of building materials and buildings)	2000
D	AUB (Arbeitsgemeinschafft Umweltverträgliches Bauproducte)	Umweltdeklarationen (environmental declarations) (under development)	2002/2003?
DK	SBI (Danish Building and Urban Research)	MVDB (Environmental Product Declaration for Building Products) (under development)	2002 (?)
F	AIMCC (French Construction Products Association) based on AFNOR (French standardization organization) standards	Experimental standards - Information concerning the environmental characteristics of construction products: • XP P 01-010-1: Methodology and model of data declaration • XP P 01-010-2: Guidelines for the application of environmental characteristics to given construction work	2001
FIN	RTS (Building Information Foundation)	Environmental Product Declaration for building products	2001
N	NBI (Norwegian Building Research Institute)	Environmental Declaration of building products	1999
NL	NVTB (Dutch Construction Products Association)	MRPI (Environmentally Relevant Product Information)	2000
NL	NEN (Dutch standardization organization)	MEPB (Material Based Environmental Profile for Building) (in development)	2002/2003?
N	Byggforsk (Norwegian Building Research Institute)	EcoDec (Miljødeklarasjoner - Environmental Declaration)	1999
S	Ecocycle Council for the Building Sector	BVD (Building Product Declarations)	1997
S	Swedish Environmental Management Council (Svenska Miljöstyrningsrådet)	Environmental Product Declaration	1997
UK	BRE (Building Research Establishment)	Environmental Profiles of Construction Materials, Components and Buildings	1999
US	NIST	BEES Building for Environmental and Economic Sustainability	2002

Buys Green, an international survey of national green procurement practices (www.iclei.org).

When do construction products contribute to more sustainable construction?

It is important to consider context: many products which are not in themselves particularly "environmentally friendly" could be exactly the right products for reducing a building's environmental impact. A particular window may not have a lower environmental impact, but the way it is used could maximize collection of low winter sunlight and block the summer sun. Creating a low environmental impact building means matching products to the specific design and site in order to optimize overall environmental impact.

We should not allow ourselves to be wooed by the idea of "green material" as the only solution to sustainability. After all, timber accredited by the Forest Stewardship Council produces just as much methane in landfills as uncertified timber. The key to greener material use is to use the material in a way that changes the "one-way trip" mentality inherent in so many applications of construction products.

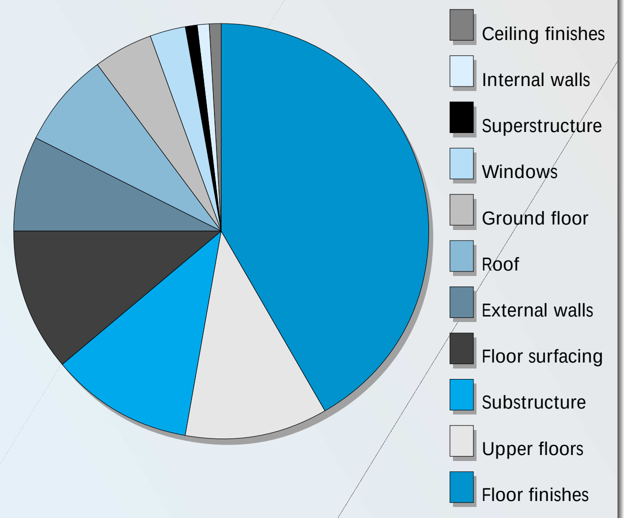
The challenge is how best to *measure* and to *manage* the impact of construction products.

By evaluating the performance of products against specific environmental parameters, it is possible for the specifier to select products and components on the basis of personal, organizational or independently chosen preferences or priorities.

A common approach to measuring the environmental impact of construction products is life-cycle assessment. How this can be applied to construction products is described below, together with a closer look at some of the most prevalent indicators currently measured – embodied energy and "recyclability".

What is clear from taking a life-cycle thinking approach is that it is not only the type of product used that is important, but also *how it is produced* (with clear links to environmental management systems) and even more importantly *how it is used* (and treated when its first life is over). As well as the tools described below, this leads to concepts like "design for adaptability" and "design for deconstruction". In the modern city environment, where building functions and fashions change so often, it may also challenge the assumption that durability and sustainability always go hand in hand.

Figure 2
Relative contribution of different construction elements to impacts of a typical office building



Source: J. Anderson and D. Shiers, *The Green Guide to Specification*, Blackwells, Oxford, 2002

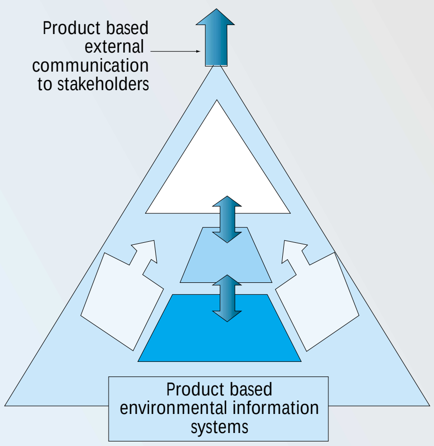
Life-cycle assessment

The data needed to measure the lifetime environmental impacts of any product or system, including construction products, can be generated using life-cycle assessment (LCA). LCA is a method for evaluating the environmental impacts of a system by taking into account its full life cycle from cradle to grave. This means consideration of all the impacts associated with production and use of a system, from the first time man has an impact on the environment till the last. This concept is expressed in Figure 1.

If we take the manufacture and use of a brick wall as an example, then using LCA we would typically consider the environmental impacts associated with:

- ◆ extraction and transport of clay to the brickworks;
- ◆ manufacture and transport of ancillary materials;
- ◆ extraction and distribution of natural gas for the brick kiln;
- ◆ mining and transport of fuels to generate electricity for use in the factory;
- ◆ production and transport of raw materials for packaging;
- ◆ manufacture and transport of packaging for bricks;
- ◆ manufacture of brick in the brickworks;
- ◆ transport of bricks to the building site;
- ◆ extraction of sand and production of cement for the mortar;
- ◆ building of the brick wall;
- ◆ maintenance of the wall, such as painting or repointing;
- ◆ demolition of the wall;
- ◆ the fate of the products after demolition.

Figure 3
Relationship between LCA and EPD



LCA must be carried out in accordance with a detailed LCA methodology (in other words, a description of rules that need to be followed). This ensures that the LCA is fair and that the results can be used comparatively. ISO standards 14040 to 14043 have been developed to standardize and define the manner in which LCAs should be undertaken. However, more precise rules are required to enable like-with-like comparisons using an LCA. Many LCA programmes have been developed to create environmental product declaration (EPD) schemes, and a number of national approaches for construction products currently exist (Table 1). There is no single harmonized approach (see below).

Making fair comparisons

One of the most important aspects of an LCA is to ensure that comparisons are made on a like-for-like basis. For example, let us say we wanted to compare the environmental impacts of two internal walls for a building – one made of aerated blockwork and one of timber studwork with timber panelling. We might well find a database that could provide us with the environmental impacts associated with production of a tonne of aerated blockwork and a tonne of kiln dried softwood. However, the comparison of the two internal walls cannot be made immediately on the basis of these two profiles. A tonne of each product would produce very different areas of wall. Instead, we need to define a "functional unit" that will enable us to compare the two internal walls.

A typical functional unit would be one square metre of internal wall over a particular building life of, say, 60 years. Included would be assumptions about repair and maintenance over the 60-year life, and about the dismantling/demolition of the wall at the end of its life.

For an external wall or roof, the functional unit also takes into account the thermal resistance of the construction to ensure that all the specifications are compared on a like-for-like basis. Some specifications may use less insulation product (and therefore have a lower initial environmental impact). However, they will also allow much greater heat loss (i.e. operational environmental impact) over the building's lifetime.

LCA design tools for buildings

This interaction between the environmental impact of the products and the overall impact of the building has prompted the development of integrated environmental design tools for build-

Table 2
Calculation tools for environmental impact assessment of buildings[4]

Country	Model owner	Model	Further information
Canada	Athena Sustainable Materials Institute	Athena	www.athenasmi.ca
Germany	IKP – Stuttgart University	Build-It	
Denmark	SBI (Danish Building and Urban Research)	Building Environmental Assessment Tool 2000 (BEAT)	www.by-og-byg.dk/english/research/environmental-impacts-from-buildings/index.html
France	CSTB	Escale	www.cstb.fr
Finland	VTT	LCA House	www.vtt.fi/rte/esitteet/ymparisto/lcahouse.html
Norway	NBI (Norwegian Building Research Institute)	Ecoprofile	www.byggforsk.no/oekoprofil/default.html
Netherlands	SBR	Eco-Quantum	www.ecoquantum.nl
	Stichting SUREAC	Greencalc	www.dgmr.nl/new/software/software_gc.html
Sweden	KTH Infrastructure & Planning	Eco-effect	hwww.infra.kth.se/bba/bbasvenska/forsning/miljoweb/miljovardering/nysammanft.pdf
UK	BRE (Building Research Establishment)	Envest: environmental impact estimating software	www.bre.co.uk/sustainable/envest.html

ing. These tools allow trade-offs between higher embodied impact and lower operational impact to be evaluated. Again, tools are now available in several countries (Table 2). Environmental impacts are compared in different ways within the tools, from a simple single environmental score to full environmental profiles.

Though not an easy task, modelling environmental impacts at building level is important since real answers concerning the environmental impact of building products are found when the whole building is considered. For example, comparing floor-covering materials with one another may not be fair if one product requires a more substantial substrate. Similarly, comparing wood and steel as light-gauge framing materials only works if insulation is included in the steel assembly to provide comparable thermal performance.

These calculation tools can demonstrate the very significant trade-offs between materials and specification choices and the operational performance of buildings. This is important; the most significant decisions about a new design are made at the very beginning of the design process, so immediate feedback on energy use and material choice is crucial. Comparison of the various tools is currently underway in the PRESCO (Practical Recommendations for Sustainable Construction) project (www.etn-presco.net).

Embodied energy

Embodied energy is the most frequently cited measure of the environmental impact of building products. Embodied energy is measured using LCA principles, collating information on total energy used in extraction, manufacture, transport, maintenance and disposal. It is normally measured in "primary" rather than delivered terms. This means it includes the energy used to produce the energy delivered to the point of use (e.g. the energy used to generate electricity or the energy used to mine for coal, as well as the energy in the fuel or power source itself).

If a whole range of processes all use the same sort of energy (e.g. coal), the embodied energy for each of these processes provides a good proxy for the amount of climate change or acid rain that each process would cause. However, different processes will use different mixes of fuel and electricity, and many fuels or energy sources can be used to generate electricity. Embodied energy figures can therefore be misleading. This will apply in particular to renewable energy sources. The other difficulty with using embodied energy as a proxy for all environmental impacts is that many products require only low amounts of energy but still have considerable impacts on the environment (e.g. through minerals extraction, waste generation and water usage). The range of issues commonly covered in an LCA give a more holistic and accurate picture of overall environmental impact.

Recycling and construction products

LCA can take account of both *actual* levels of recycled *input* and the *current* fate of products at the end of their life cycle, due to the way they are generated. A masonry product made using recycled input, for example, will have a reduced mineral extraction impact; products such as primary steel which are recycled are sometimes calculated to have lower impact if the LCA methodology used passes some of the environmental impacts associated with primary manufacture on to future recycled phases of the product's life.

The merits of recycling should be judged on a case-by-case basis. However, it is important that we do not choose products that may *potentially* be recycled tomorrow at the expense of recycled products that are available today. Passing the responsibility to future generations does not reflect the spirit of sustainable development.

Ensuring that buildings are designed so that products can be either reused (as a preference) or recycled is very much the responsibility of today's designer and is embraced by the concept "Design for Deconstruction". This is the subject of an international task group (CIB TG 39, "Deconstruction", www.cibworld.nl).

The importance of different elements

BRE calculated the embodied environmental impacts relating to a typical UK office building and broke them down into constituent elements. The contribution of each building element is shown in Figure 2. This includes all the elements of the building, including substructure and superstructure, and covers the maintenance and replacement of elements over the 60-year life.

Floor finishes contribute the largest impact because they are typically fossil fuel intensive and replaced frequently. Choosing lower impact products can significantly reduce a building's overall lifetime impact. In addition, raised access floors offer flexibility while floor surfaces contribute the third most significant embodied impact.

Of the major design elements, windows have the lowest impact (only 3% of the building total). For a building with higher glazing ratios, the impact of windows will increase as the impact of the external walls reduces.

The choice of structure makes very little difference to the overall impacts of the building since both cement and steel account for around 2% of the total.

Green procurement

Two important decisions affect procurement of building products and its impact on the environment: *what to buy* (i.e. the product type) and *from whom to buy it.*

General LCA information provides assistance to specifiers on what to buy. Deciding from whom to buy can be determined in a variety of ways. Clients might use certification to ISO14001 or an EMAS environmental management system as an indicator of good performance by a supplier. Alternatively, specific measures such as use of local or low-impact raw materials or low-emission technologies may also be useful.

Neither an Environmental Management System nor evidence of a "single issue" approach to environmental impact help clients to decide how a particular manufacturer's product compares to the typical product across the wide range of issues that need to be considered. Many manufacturers are therefore now turning to LCA in the form of environmental product declarations (EPDs) to communicate their own environmental performance to their customers.

The ISO 14025 Technical Report: Environmental Labels and Declarations – Type III Environmental Declarations gives guidance on how a producer can provide quantified environmental life-cycle product information. The information is presented across a range of indices relevant to the product category. The objective of such a declaration is "to encourage the demand for, and supply of, those products and services that cause less stress on the environment, thereby stimulating the potential for market driven continuous environmental improvement" (ISO 14020). The relationship between LCA and EPDs is illustrated in Figure 3.

Specifiers can ask their suppliers for environmental product declarations to satisfy themselves that the company they are using takes a responsible attitude to management of their environmental performance. Choosing lower lifetime environmental impact solutions often goes hand in hand with lower whole-life cost solutions, creating a double business benefit.

Towards harmonization

Many companies manufacture in several countries. They therefore wish to see the range of schemes listed in Table 1 harmonized in order to allow more economic use of LCA and environmental product declarations across their business.

The International Organization for Standardization Committee on Sustainability in Building Construction (ISO/TC59/SC17) is working to create, *inter alia*, an international standard for environmental declarations for building products parallel to the more general activity on EPDs of a separate committee (ISO/TC207/SC3/WG4). The European Commission published a comprehensive report in 2002 which described the different schemes currently in operation and considered opportunities for harmonization.[5] SETAC (the Society of Environmental Toxicology and Chemistry) has produced a state of the art report that is helpful in demonstrating the basis on which harmonization can be achieved.[6]

Conclusions

The overall performance of the building is the most important consideration in achieving more sustainable construction. Construction products must be chosen in this context. The most successful approach to specification is one in which underlying objectives and priorities are clearly established at the early stages of a project, as this can then help determine the appropriate balance between environmental and technical requirements. Taking a life-cycle approach is a significant and very positive step in the right direction.

Life-cycle thinking made simple:
The Green Guide to Specification

Upper floors

Element	Summary rating	Climate change	Fossil fuel depletion	Ozone depletion	Human toxicity to air and water	Waste disposal	Water extraction	Acid deposition	Ecotoxicity	Eutrophocation	Summer smog	Minerals extraction	Cost £/m²	Typical replacement interval	Recycled input	Recyclability	Recycled currently	Enery saved by recycling
Beam and blockwork floor with screed	A	A	A	A	A	A	A	A	A	A	A	A	47-73	60	A	C	C	A
Hollow precast reiniforced slab and screed	A	A	A	A	A	A	A	A	A	A	A	A	47-73	60	C	A	C	A
Hollow precast reiniforced slab with structural topping	B	B	B	A	B	B	B	B	A	B	A	B	50-80	60	C	A	C	A
In situ reinforced concrete slab	C	B	B	A	B	C	B	B	A	B	A	C	40-60	60	C	A	C	A
In situ reinforced concrete trough slab	B	A	A	A	A	B	A	A	A	A	A	B	40-60	60	C	A	C	A
In situ reinforced concrete waffle slab	B	A	A	A	A	B	A	A	A	A	A	B	40-60	60	C	A	C	A
Lattice girder precast concrete floor with in situ concrete topping	B	A	A	A	B	B	A	A	A	A	A	C	84-153	60	C	A	C	A
Lattice girder precast concrete floor with polystyrene void formers and in situ concrete topping	B	B	C	A	A	A	A	B	A	A	A	A	84-153	60	C	B	C	C
Profiled steel permanant steel shuttering, in situ concrete slab, steel reinforcement bars and mesh	B	B	C	A	A	B	C	A	C	A	C	B	55-120	60	C	A	A	A
Solid prestressed composite floor with structural topping	C	C	C	A	C	C	C	C	A	C	A	C	65-90	60	C	A	C	A

The third edition of *The Green Guide to Specification*, a simple guide for design professionals, was published in 2002. It provides environmental impact, cost and replacement interval information for a wide range of commonly used building specifications, using simple A, B, C ratings. The *Green Guide* uses a normalized and weighted approach to analyzing data, allowing environmental information to be added together. A-rated products have the lowest scores, C-rated the highest.

Notes

1. Anink, D., et al. (1996) *The Handbook of Sustainable Building: Ecological Choice of Materials in Construction and Renovation*. James and James (Science Publishers), London.
2. Targeted Research Action – Environmentally Friendly Construction Technologies (www.traefct.com).
3. Tables 1 and 2 are adapted from DG Enterprise European Commission and PricewaterhouseCoopers, *Comparative study of national schemes aiming to analyse the problems of LCA tools and the environmental aspects in harmonised standards*, 2002 (http://europa.eu.int/comm/enterprise/construction/internal/essreq/environ/lcarep/lcafinrep.htm).
4. See note 3
5. Anderson, J., and D. Shiers (2002) *The Green Guide to Specification*. Blackwells, Oxford.
6. Kotaji, S., Schuurmans, A. and Edwards, S. (eds.) (June 2003) *Life Cycle Assessment in Building and Construction*. SETAC (www.setac.org). ◆

On the sustainability of concrete

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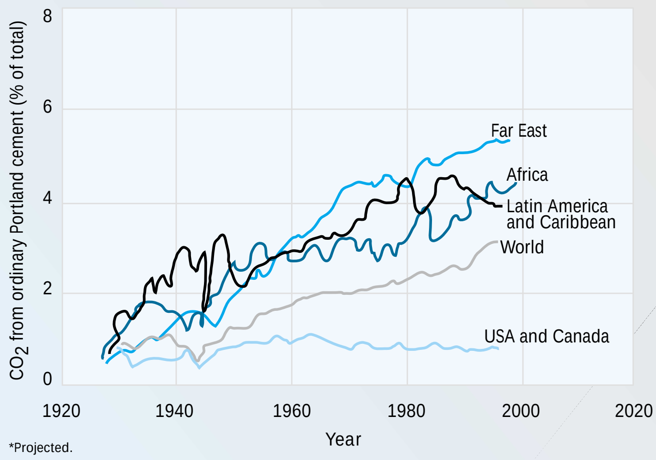
After several important technical improvements, concrete made with Portland cement is probably the world's most used man-made material. Global cement production in 1997 was 1.57 billion tonnes (Humphreys and Mahasenan, 2002). That much cement, mixed with water, gravel and other substances, equals some 1.05 trillion tonnes of building material to produce houses, office buildings, sewage pipes, dams, concrete roads, etc.

Cement production is widespread: plants are found in 150 countries (Marland et al., 2002), with China being responsible for roughly one-third of the total. Global cement production is increasing as consumption in developing countries rises: between 1990 and 2000, production grew 55% in developing countries and 3% in the developed ones. Cement demand in 2020 is expected to be 120-180% higher than in 1990, with most of the growth in developing countries (Humphreys and Mahasenan, 2002).

The basic way to make Portland cement is to heat a mixture of limestone and clay – two largely available, natural, non-renewable materials – in a kiln at about 1500°C to produce cement "clinker". After cooling, the clinker is finely ground and mixed with gypsum and, frequently, other finely ground materials such as fly ash and blast furnace slag to produce various commercial varieties of cement.

Figure 1
CO_2 released in limestone decomposition during cement production, selected regions, 1920-2020*



*Projected.
Source: Marland et al., 2002.

Cement production and the environment

The major global impact of cement production is global warming. Humphreys and Mahasenan (2002) estimate that the cement industry is responsible for 3% of global anthropogenic greenhouse gas emissions and 5% of global anthropogenic CO_2 emissions. About half the CO_2 is released by limestone decomposition in the kiln – "cement process CO_2" (Humphreys and Mahasenan, 2002; Gale and Freund, 2000) – and the other half is due mainly to fuel burning (Figure 1).

CO_2 release rates differ among countries, depending on a) production process, b) clinker content, c) energy efficiency in the calcination phase, which is responsible for 90% of energy consumption (Gale and Freund, 2000), and d) differences in fossil fuels' carbon content. Old cement plants are less energy efficient and sometimes still use the wet process, which consumes 20-40% more energy (Gale and Freund, 2000).

Cement production also generates emissions of NO_x, SO_x, dust, dioxins, etc.

Blending materials

Mixing clinker with other materials, a process called "blending", reduces CO_2 emissions and increases energy efficiency during cement production.

Table 1 presents the most common blending materials. Fly ash (including from cement-making itself) and blast furnace slag are the types of waste most used in blending. Their use could be greatly increased except where local shortages exist.

Clinker content can range from about 95% (when only gypsum is added) to 5%. In the mid-1990s average clinker content was 88% in the US, 80% in Japan and 70% in Europe. The overall trend has been towards decreasing clinker content.

Recent research into new sources of blending materials has concentrated on waste from agriculture, industry and mining, including ash from burning lignocellulosic material (e.g. rice husk), fly ash slag from municipal solid waste incineration, paper mill sludge ash, colemanite waste and ceramic waste.

Concrete and the environment

Concrete typically contains 8-15% cement, 2-5% water, about 80% aggregates (e.g. gravel, sand, limestone filler) and less than 0.1% chemical admixtures.

Despite its size, the 80% share of natural or recycled aggregates causes less than 3% of total emissions and energy use in concrete production (Vares and Häkkinen, 1998). Hence cement content and composition, as determined by engineers and architects, determine the concrete's environmental load.

For a constant set of materials, the cement content is a function of the desired mechanical strength, production variability, service life requirement and concrete workability, along with the nature of the admixtures used.

Chemical admixtures can reduce the cement consumed for a given strength, or increase concrete workability, without increasing cement consumption. A modern concrete mix design, combining several aggregate grades with admixtures, produces a more eco-efficient concrete. Minimiz-

Table 1
Most common blending materials used in cement production

Material	Description	Nature
Blast furnace slag	Pig iron by-product	Waste
Fly ash	Coal combustion by-product	Waste
Silica fume	Silicon metal/ferrosilicon alloy by-product	Waste
Natural pozzolan	Volcanic ash	Natural
Burnt clay	Pozzolan calcinated at ~700°C	Industrial
Limestone filler	Ground limestone	Natural
Metakaolin	Kaolin (a special clay) calcinated at ~700°C	Industrial

Source: author

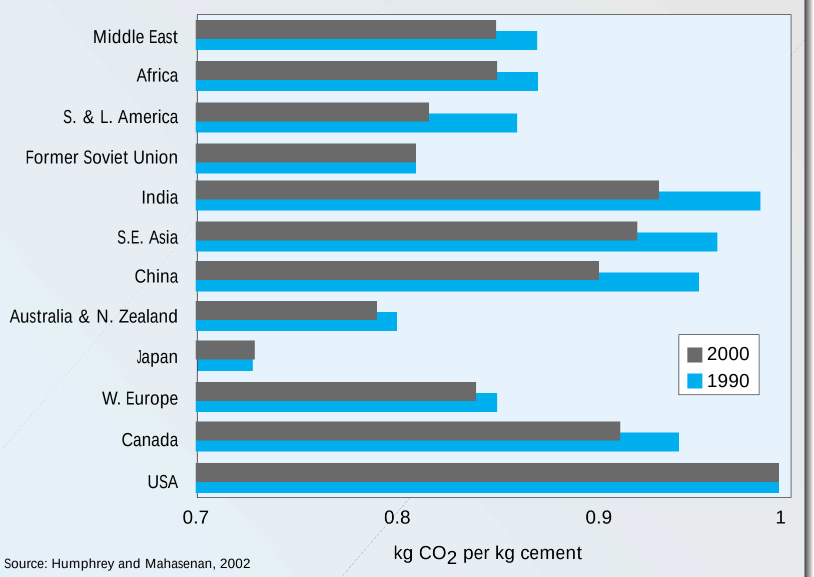
ing concrete production variability by using adequately trained personnel, carefully selected raw materials and more sophisticated proportioning and mixing equipment, as most ready-mix companies today can do, is also an effective way to reduce concrete's environmental impact.

When concrete is made on site by do-it-yourself home builders or small contractors, the above approaches are not viable. In Brazil, for instance, 68% of the cement sold is bought by building material dealers and used with little or no controls.

A large share of concrete used worldwide is reinforced with steel. In Brazil most steel rebars are made by recycling steel scrap in electric mini-mills. In countries where the steel for concrete reinforcement is often made from virgin pig iron, the environmental impact is higher. Steel's contribution to the environmental load of reinforced concrete is greater than that of the aggregates but much less than that of the cement.

Figure 2

CO_2 release per kg of cement produced, selected regions



Source: Humphrey and Mahasenan, 2002

Service life

Increasing the service life of concrete structures is a very efficient way to improve the eco-efficiency of the global economy. Service life can be dramatically extended with little or no increase in – or even a reduction of – the environmental load. Doubling the thickness of the concrete over the steel rebar from 10 mm to 20 mm, for instance, quadruples the service life of reinforced concrete, defined as the time it takes carbonation reach the rebar, but increases concrete consumption by only 5-10% (Helene, 1993). In marine environments, a high blast furnace slag or fly ash content can increase service life and decrease the environmental load.

At the end of its service life, most concrete can be recycled as aggregate or even in cement production. But because natural aggregate is usually cheap, concrete is not extensively recycled except in a few European countries (e.g. the Netherlands). In Brazil, as in most developing countries, only local authorities run recycling plants processing concrete and other construction and demolition waste, and the resulting aggregate is generally used as road base. Additional recycling opportunities for such waste need to be investigated.

Making concrete a more sustainable material

Aside from some specialized applications such as the use of chalk or glue as mortar, there are currently no viable alternatives to clinker-based cement and concrete, and despite intensive research it will probably take decades to develop any. And while the technical options mentioned above, along with other technologies, can increase the sustainability of concrete and are available on markets worldwide, they are not always explored.

The first reason seems to be lack of knowledge/awareness on the part of professionals and authorities. With few exceptions, there is almost no technical reason to use cement with high clinker content, but many engineers and architects still prefer it. Designing reinforced concrete structures for an extended service life is a relatively new, often unfamiliar concept that needs to be refined and has not yet been incorporated into concrete design codes and standards, which sometimes set a minimum of cement consumption in structural concrete. Much effort is needed in the technical and environmental education of civil engineers and architects, and to change design codes and create incentives to use blended cement.

Other barriers are market based. Old, inefficient cement plants may still be competitive. Advanced admixtures can be expensive. Ready-mix concrete sometimes costs more than concrete produced at the building site, so DIY builders and small contractors often prefer the latter option. Here the need is to balance social sustainability with environmental sustainability.

Finally, concrete's sustainability must be judged in real situations. A generic life-cycle assessment approach that may work for more standardized materials, like plastics and metals, will seldom be adequate to evaluate concrete. There is a great need for more accurate and independent data about life-cycle loads of cement – and other building materials – especially in developing countries.

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Bamboo in construction: status and potential

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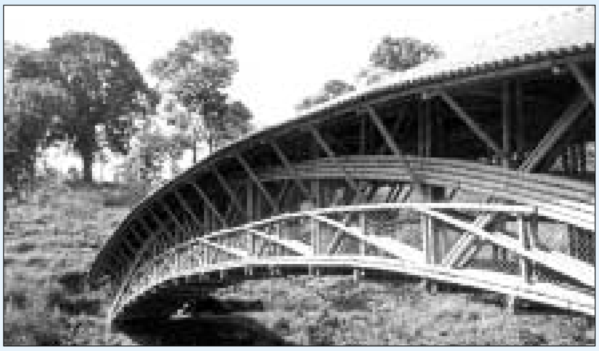
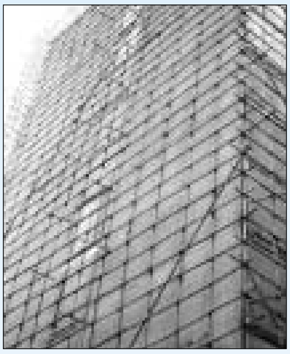
Bamboo is a well established cultural feature in many regions of the world. Its diversity and versatility are well documented. Some 1250 species and 1500 traditional applications have been identified. The main users are the rural poor, and it is perhaps for this reason that bamboo has largely been taken for granted by the wider community. As a material resource, bamboo has not received the mainstream recognition it deserves.

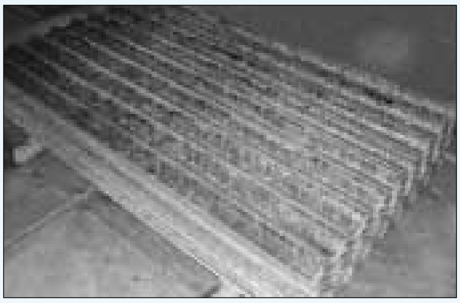
Bamboo is the fastest growing woody plant on the planet. However, it actually belongs to the grass family. Most species produce mature fibre in about three years, much more rapidly than any tree species. Some species grow by up to one metre a day, and the majority reach a height of 30 metres or more.





52 metre bamboo road bridge by Jorg Stamm (Colombia) and bamboo scaffolding (Hong Kong)

Bamboo has exemplary "green" credentials. It is adaptable to most climatic conditions and soil types, acts as an effective carbon sink and helps counter the greenhouse effect. It is being used increasingly in land stabilization to check erosion and conserve soil. It can be grown quickly and easily, even on degraded land, and harvested sustainably on three- to five-year rotation. Bamboo is a truly renewable, environmentally friendly material.



Corrugated bamboo matboard (IPIRTI, India) and laminated bamboo flooring

The bulk of bamboo is gathered from the wild or rural environment, but in many areas bamboo resources have dwindled due to overexploitation and poor management. This issue needs to be addressed through well organized and managed cultivation if bamboo utilization is to develop on a sustainable basis. Plantations are already being raised in China and India to support the pulp and paper industry.

A billion people worldwide live in bamboo houses. For the most part they are low-grade, impermanent buildings, belying the material properties of bamboo and doing little to promote its image as a viable construction material. At little extra cost these buildings can be upgraded to provide safe, secure and durable shelter, benefiting the most vulnerable members of society.

Possibly the major factor contributing to the view of bamboo as a temporary material is its lack of natural durability. It is susceptible to attack by insects and fungi. Its service life may be as low as one year when in ground contact. However, the durability of bamboo can be greatly enhanced by appropriate specification and design and by careful use of safe and environmentally friendly preservatives such as boron.

The main structural advantages of bamboo – its strength and light weight – mean that properly constructed bamboo buildings are inherently resistant to wind and earthquake. These properties can be effectively exploited through careful yet simple design and detailing.

Even when issues of durability and strength are resolved, the question of acceptability remains. A bamboo building need not look "low-cost" or even necessarily look like bamboo! Imaginative design and the use of other locally available materials within the cultural context can make the building desirable rather than just acceptable.

Bamboo: the international view

Bamboo has a long history as a building material. It is widely used in construction throughout the world's tropical and sub-tropical regions, with a range of applications to match or even exceed those of timber. Bamboo buildings of every description can be found in Central and South America, from low-grade temporary shanties to exclusive, architect-designed mansions.

Bamboo products for use in construction are increasing in availability. They range from bamboo mat boards (flat and corrugated), to more sophisticated panel products such as fibreboard, "plyboo" and flooring, to large laminated sections (now under development) for use in external joinery. Costs are currently similar to those of equivalent timber products. Bamboo will therefore find a market where timber is in short supply, or where it is specified for architectural reasons. In Europe there is a small but flourishing market in bamboo for internal applications (e.g. flooring) but not as yet for structural ones.

Bamboo use is not restricted to building. Bamboo has been used as concrete reinforcement, and development work is continuing in this field. Bamboo is used for light traffic bridges, and the feasibility of constructing large span bridges carrying vehicular traffic has recently been demonstrated in Colombia. Bamboo as scaffolding is well known (40-storey construction is not uncommon in the Far East), and its use is set to increase as a result of the development of a design and erection guide in Hong Kong Kong.[1]

Other construction applications include ground stabilization, through the use of retaining walls and piling, and coastal protection (recently trialled in Sri Lanka).

TRADA's experience

TRADA (the Timber Research and Development Association) is an internationally renowned centre for forest product engineering and technology. Its origins can be traced to 1934. TRADA is based in the UK, with operations worldwide.

TRADA has recently completed the first phase of a project in India to develop and promote a cost-effective bamboo based building system. This project is designed to provide safe, secure and durable shelter at a cost that is within reach of even the poorest communities in developing countries. It has demonstrated that with careful specification, detailing and environment-friendly preservation, the life of bamboo can be extended to match that of other building materials.

Prototype testing provided an effective visual demonstration of the performance and strength of components and assemblies, as well as of the resistance of walls and roofs to wind, earthquakes and impacts.

The building system costs around half that of traditional brick, block or reinfoced concrete construction. It is one of the cheapest permanent methods of building yet developed. It is also sustainable, simple to erect, strong and durable, incorporating all the essential requirements for affordable shelter. Moreover, the basic system can enhanced through improved use of shape, space and colour at little or no cost. Overall, the system effectively demonstrates that desirability and quality are fully compatible with affordability.

In its second phase (2000-05) the project will be extended to Bangladesh and Sri Lanka. The technology will be applied in the development of designs for larger community buildings such as schools and health clinics. Use of bamboo for construction of footbridges in rural areas will also be investigated, with the development and testing of prototypes.

Bamboo's potential

Taking into account all that bamboo has to offer, it is well placed to address four major global challenges:

- *shelter security* through provision of safe, secure, durable, affordable housing and community buildings;
- *livelihood security* through generation of employment in planting, primary and secondary processing, construction, furniture and manufacture of high value-added products;
- *ecological security* through conservation of natural forests by substitution of primary timber species, as an efficient carbon sink, and as an alternative to non-biodegradable and high-embodied energy materials such as plastics and metals;
- *sustainable food security* through agro-forestry systems, by maintaining the fertility of adjoining agricultural lands, controlling erosion. Bamboo is also a direct food source.

The challenge now is how to share this knowledge: to bring it to the attention of a wider audience and demonstrate that the new technologies are equally viable in areas which have not had exposure to the "new thinking" and, above all, to deliver the benefits it promises to the poorest members of society.

Future requirements

Sustainable supply

A policy of organized planting, careful management of plantations and natural stands, and appropriate regulation of supply are prerequisites for any other interventions aimed at promoting bamboo as a building material.

Standardization

Lack of guidance on use of bamboo in building has been a major obstacle to its wider adoption. Draft international standards ISO 22156 and 22157 represent the first step towards addressing this problem. New or amended national regulatory instruments such as manuals, codes of practice, specifications, building regulations and standards are now required.

Research and extension activities

The will must exist at government level to explore the potential of alternative materials, and to put in place the resources and mechanisms to carry out necessary material developments and evaluations. Where this capacity already exists, it is often necessary to reorient the approach of research institutions to link them directly with the building industry, together with their government and private sector clients.

Training

Curriculum revision is required to give greater emphasis to the new technologies. This would apply to institutions training high-level artisans or technicians for the construction industry, as well as professionals such as architects, building technologists, civil, structural and mechanical engineers, and quantity surveyors.

Fiscal policy

Financial incentives are required in order to encourage the establishment and support of industries involved with the new technologies. In addition, the widespread policy which limits the advance of bank loans and mortgages on "bamboo" houses must be reviewed.

Demonstration and quality

Effective dissemination aimed at popularizing the new technologies is vital, considering the negative perceptions held by many about bamboo in building. Even when issues of durability and strength are resolved, the question of acceptability remains. Construction of model buildings is therefore essential to overcome prejudice and boost the confidence of specifiers (e.g. architects, engineers, builders) and users. In this regard the quality must be the highest achievable, since any shortcomings in the standard of construction, detailing and finish will be reflected, unfairly, on the building system as a whole.

1. Draft documents prepared by the University of Hong Kong .

Procurement of sustainable construction services in the United States: the contractor's role in green buildings

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Summary

Successful sustainable building design and construction processes are characterized as collaborative and interdisciplinary. In many cases, however, procurement of construction services is not perceived as one of the necessary steps in the design and delivery of a sustainable building project. Contractors are often viewed merely as brokers of construction services, who simply follow drawings and specifications and are able to contribute to sustainable building projects only through job site recycling plans. Research on the role of construction management organizations in the successful delivery of high-performance sustainable buildings is being carried out at Penn State University and the Partnership for Achieving Construction Excellence (PACE). The objectives are to identify the value of construction services in the processes and decision-making that are critical to sustainable building projects, and to develop proactive techniques for engaging construction organizations in collaborative sustainable design and construction processes.

Résumé

Les procédés efficaces pour un développement durable en matière de conception et de construction des bâtiments se distinguent par leur nature collaborative et interdisciplinaire. Pourtant, dans de nombreux cas la fourniture des services de construction n'est pas perçue comme l'une des étapes nécessaires de la conception et de la réalisation d'un projet de construction dit durable. Les entreprises du bâtiment sont souvent considérées comme de simples prestataires de services de construction qui se contentent de suivre des plans et des spécifications, et dont la contribution aux projets de construction durable se limite à des programmes de recyclage sur le chantier. Des recherches sur le rôle des organismes de gestion des projets de construction pour livrer des bâtiments durables de haute qualité environnementale sont actuellement menées par la Penn State University et le Partnership for Achieving Construction Excellence (PACE). Les objectifs sont de déterminer la valeur des services de construction dans les procédés et le processus décisionnel critiques pour les projets de bâtiment durable et d'élaborer des techniques favorisant l'initiative pour faire participer les entreprises du bâtiment à des processus collaboratifs de conception et de construction durables.

Resumen

La colaboración y los aportes interdisciplinarios son característicos del diseño de edificios sostenibles y de los procesos de construcción exitosos. Sin embargo, en muchos casos, el procedimiento para la obtención de servicios de construcción no se considera como uno de los pasos necesarios en el diseño y la ejecución de un proyecto de edificio sostenible. Se piensa a menudo que los contratistas son sencillamente corredores de servicios de construcción que se guían por diseños y especificaciones y que sólo pueden contribuir a los proyectos de edificios sostenibles con planes de reciclaje para las obras. Penn State University y PACE (Asociación para lograr una construcción de excelencia) están llevando a cabo investigaciones sobre el rol de organizaciones para la gestión de la construcción en la realización exitosa de edificios sostenibles de alto rendimiento. Los objetivos son identificar el valor de los servicios de construcción en los procesos y en la toma de decisiones, fundamentales para los proyectos de edificaciones sostenibles, y desarrollar técnicas proactivas para obtener la participación de las organizaciones de construcción en procesos de colaboración de diseño y construcción sostenibles.

Long recognized as a major contributor to global depletion of natural resources, the US construction industry is finally making strides in its efforts to achieve more sustainable building projects. Along the way, design and construction organizations face new challenges and the need to rethink their approach to almost every aspect of their operations. Many are finding that efforts to become more sustainable also create incentives to adopt logical and much needed improvements to the traditional sequential design and construction process.

In an industry that has clung to traditions of dysfunctional business practices and adversarial team relationships, many are beginning to realize that sustainable building projects might be more appropriately referred to as *sensible* building projects. For the purposes of this article, the term "green buildings" has been adopted (i.e. projects in which efforts are made to minimize the environmental impact of construction, and to maximize energy efficiency and the productivity of occupants).

Most architecture, engineering and construction organizations agree that the popularity of green buildings will continue to grow, but few have produced definitive conclusions about the impact of this shift on their organizations. The design profession, which has clearly embraced this emerging trend, has largely dominated discussions of green design and construction. However, many owners are finding that construction organizations can also play a key role in green building projects.

When the Toyota Motor Corporation (TMC) decided to construct a new facility for its US Financial and Customer Service Centres, the TMC Real Estate and Facilities philosophy, "Process Green", was implemented on the project. The contractor selected, Turner Construction Co., played an unexpectedly valuable role, achieving Leadership in Energy and Environmental Design (LEED) Gold Certification. Besides working closely with the design team, some examples of how Turner contributed include 98% recycling of construction waste – far exceeding the project goal of 70%. Moreover, through detailed management of indoor air quality issues during construction, significant time was saved in commissioning and start-up of what is now the largest LEED (version 2.0) gold certified facility in the US.

Success stories are in abundance. What common practices explain their success? Research in progress at Penn State University seeks to define enabling processes and team functions that result in sustainable building solutions, with a particular emphasis on how to actively engage construction organizations on green building projects and position them as value-added contributors.

Current perceptions

Through case studies of over 20 green building projects and interviews with more than 40 industry professionals in the US, the perceptions of owners, design professionals and construction organizations concerning the contractor's role in green building projects were assessed. The purpose of the first phase of this investigation was to define factors that could increase or diminish the engagement of construction organizations on green building projects.

Several parallel and contributing factors were identified:

◆ Green building projects demand open lines of communication between disciplines They typically involve more complex interdependencies between building systems and project organizations than do traditional projects. Thus they are thus best serviced by *inclusive* and *integrated* project teams.

◆ The LEED rating system has been rapidly accepted, as the US construction industry was starved for a set of metrics to assess the "greenness" of a building. However, what began as an assessment mechanism for the final product – a green building – has resulted in significant process implications for designers and builders. These processes (how to best make green buildings) are still largely undefined.

◆ In the US the leading owners seeking green buildings are government agencies such as the General Services Administration, the US Navy, and many state and local governments. At the same time, a large number of these agencies are moving towards the use of *design-build* delivery systems in which construction organizations are highly involved during project design.

◆ Most owners and professionals hold the opinion that green buildings cost more than traditional ones. While a longer-term view of sustainable buildings makes initial premiums paid for higher performance facilities seem small in comparison to potential gains in energy efficiency and worker productivity, we must face the reality that the industry will be slow to move away from a short-sighted *first cost perspective*.

◆ Progressive and forward-thinking construction firms are adopting *lean principles* proven in the manufacturing community to reduce waste and inefficiencies in construction processes. Green principles and lean principles are closely aligned in their goals of maximizing total process efficiency and reducing waste.

Each of these factors implies that perceptions of the role of construction organizations will likely broaden as the industry becomes more adept at delivering green buildings.

Toyota Motor Corporation's US Financial and Customer Service Headquarters, Torrance, California

Pentagon renovation project in Washington, D.C.

The next phase of this research was to examine green building case studies in detail to garner impressions from owners, designers and construction professionals on the key roles of construction organizations. Many differing opinions were revealed. Owners were found to have the broadest perspective with respect to how construction firms can assist during both design and construction; design professionals as a group had the narrowest perspective.

The most significant ways in which construction firms can contribute include the most obvious, such as estimating and jobsite recycling. Nevertheless, case studies show clearly that construction firms, given the opportunity, have the potential to make useful contributions to all phases of green building projects including the areas of material selection, indoor air quality management, and the vast need to educate specialty contractors about green building methodologies and processes. Not surprisingly, the broadest and most comprehensive point of view came from design-build teams.

While there is no shortage of differing views and opinions, particularly between traditional design firms and progressive construction firms, trends and consistencies are emerging that help shape a more systematic movement towards achieving sustainable construction goals. Among these, one notable trend is recognition of the valuable contributions of members of an integrated project team that includes construction organizations.

Value added by construction organizations

As progressive construction organizations gain experience with green building projects, they will be better equipped to articulate specific services and competencies that could contribute to the success of these projects. Four key areas of contribution have begun to surface as the most vital: estimating, green building materials, waste minimization and recycling, and indoor air quality management.

Estimating

The value of construction organizations in providing estimating services on a green building project is indisputable. This value is amplified when accurate estimating in the early phases of design permits accurate cost information to be included in the preliminary selection of building systems and materials.

Case studies of green building projects clearly show that implementing sustainable project requirements mid-stream will result in cost premiums for "add-on" sustainable features. However, if sustainable project features are made a priority in a project's earliest stages, it is widely held that these features will not have to add to the project's overall cost. High performance and sustainable project features need to be selected based on the owner's budget and priorities and on accurate cost information. With this in mind, the role of construction organizations in project estimating is vital for green building projects during planning and preconstruction as it provides timely cost information about design decisions.

From a broader perspective, it is also the contractor's responsibility to understand the high integration of systems on a sustainable building project. As building systems become more integrated, incorporation of green elements can require a redesign of other systems. For example, more reflective paint can improve the efficiency of an indirect lighting system and allow reductions in the size of electrical and cooling systems. In many cases, however, these interdependencies are not fully exploited. Instead, redundancies in building designs are maintained.

An emerging concept called "total project costing" advocates the practice of seeking cost savings in a project's less crucial areas to facilitate the higher initial cost of energy efficient building systems and environmentally friendly building materials. Thus it is the role of construction organizations to assist the design team with pricing methods that acknowledge the interlinked benefits of a variety of systems (i.e. moving from materials-based to system-linked cost estimates, so that the calculated life-cycle costs and integrated system costs clarify the benefits of green building systems). While some construction organizations are quite capable of implementing this approach, their input will be muted if it is not embraced in the early stages of a project.

Green building materials

A wide variety of new environmentally sensitive building materials are available. Many design professionals surveyed as part of this project viewed the selection of materials as being strictly the job of design firms, with construction organizations only needing to follow detailed specifications to meet sustainable material requirements. However, contractors can complement this process, as demonstrated by many case study projects. Caulk, joint sealants, drywall compounds, fireproofing materials, adhesives, duct cement and insulation are all items that should be selected with the same environmental considerations as those for finish materials. A more holistic approach to procurement of building materials that meet a project's environmental objectives is needed. The knowledge of general and specialty contractors can be invaluable in this effort.

Contractors have increasing responsibility to become familiar with the environmental impacts of building materials. A baseline understanding may be a good start for long-term benefits to projects and to their own company, but a deeper understanding of environmentally sensitive products is needed. Additionally, contractors' role of ensuring proper handling, storage, installation, finishing and cleaning, and training maintenance personnel on long-term care of materials, increases their understanding of the characteristics of "green" materials.

When presented with unfamiliar materials in project specifications, the first reaction of construction organizations is suspicion – of potentially higher costs, more complex or unfamiliar jobsite handling and construction methods, and lower productivity. If they are given the opportunity to investigate the true impact of a new material on a project, construction organizations can more accurately determine whether the material is best suited to the project and provide realistic costing information, rather than prices inflated due to undefined potential risks.

Detailed sole-source specifications place material vendors in a position to charge whatever they wish, typically resulting in higher costs. Construction organizations routinely solicit competitive materials pricing from multiple vendors and can often utilize collective purchasing to obtain lower prices. One approach taken by more experienced owners (e.g. the US Department of Defense and the US Navy) to mitigate this problem is to adopt performance-based requirements that replace detailed specifications and give contractors the opportunity to find innovative solutions that achieve the performance goals of materials and systems.

Construction waste minimization and recycling

Many design and construction professionals state that the "green" role of a construction organization is limited to jobsite recycling. As contractors are only beginning to be asked for wider services on sustainable building projects, this may often be the case. However, implementing a jobsite recycling plan just because it is mandated in project specifications is a one-dimensional approach to sustainability. In most regions of the US it is cheaper to landfill waste than to recycle it. Recycling can and must be market driven, and be initiated by legislation or regional constraints that make landfill more expensive than recycling and reward recycling efforts.

Once infrastructure is developed for recycling construction waste, and a market is created for recycled content products, contractors will not need to be convinced – or need to be required to do it. The State of Washington led the US in initiating a recycling paradigm at both public and private levels. As a result, Seattle-based Sellen Construction was among the first to suggest that the money saved by diverting construction waste from landfills should be incorporated in the project budget to defray the higher costs of using recycled content materials. This allows owners to see no net cost increase for choosing recycled materials and, perhaps more importantly, helps drive the emerging market for recycled building materials.

Through experience and alliances with waste haulers, many construction firms have become quite adept at recycling and the related jobsite psychology and infrastructure needed to fully implement a waste minimization and jobsite recycling plan. Often these company based policies result in diversion rates of up to 80%, far in excess of a mandated recycling programme.

Indoor air quality

Achieving a healthy building is a primary tenet of green design and construction. Construction methods have direct implications for indoor air quality. Examples include protecting HVAC systems from pollutants, building time into construction schedules to purge buildings of harmful emissions, and sequencing work to minimize exposure of materials to potential contamination, particularly wet materials that could lead to growth of mould and paints and finishes that contain harmful volatile organic compounds.

As demonstrated by the Toyota case, Turner Construction's efforts to manage indoor air quality during construction proved highly valuable to the commissioning process. Toyota's Director of Corporate Facilities, Sanford Smith, singled out commissioning as the most important element of delivering a facility. He stated that "Construction is the building of a continuum," referring to the interwoven nature of construction and operations and the value of a commissioning process that ensures a building is functioning as intended.

During this study most architects and contractors were found to agree that if indoor air quality requirements are not specified on a project, they would not be met. However, recent threats of mould and related liability issues are increasing the value of steps taken during construction to maintain indoor air quality. In addition, significant research has shown the increased risk of infection due to hospital and laboratory construction. For these reasons alone, many contractors have learned that commissioning costs will be reduced and exposure to mould or water damage minimized by focusing on indoor air quality management during planning and construction. These efforts will also drastically minimize the risk of any present or future contamination of the building and its occupants. As contractors get better at managing these new risks, their expertise will help contribute to meeting indoor air quality requirements on green building projects.

Making a case for integrated teams: renovation of the Pentagon

The largest office building in the world is the home of the US Department of Defense. The Pentagon is emerging as one of the country's best examples of green design through the processes used and the design solution for its 585,000 m^2 renovation.

Some key project features include:

- maximum use of daylighting and materials made from recycled content such as carpet and ceiling tile;

- a high-performance mechanical system that requires minimal ductwork for air distribution, drastically reducing the space needed for mechanical equipment in rooms and ceilings;
- a Universal Space Plan that permits modular and repetitive construction processes *and* minimizes the effort and waste generated by frequent reconfigurations of spaces;
- prefabricated "smart walls" which include all power and communication systems and are combined with high-tech support spaces to simplify construction sequences, facilitate reconfiguration, and minimize waste during construction;
- recycling requirements authored by the project teams which, because of the project's massive size, have spurred development of a recycling infrastructure in the region that will benefit other projects.

How was this accomplished? The credit goes to the Pentagon renovation team, including a management organization that crafted performance-based specifications for the project – a large collaborative design-build team that embraced the sustainability goals of the owner.

Still under construction, the Pentagon renovation also provides an excellent example of the synergies between sustainability and *constructability*, and how construction organizations can contribute to the design of an energy efficient and environmentally conscious solution *and* observe significant savings in productivity through waste minimization and elegant design-build solutions that simplify construction. As these synergies are recognized by project teams, they will help further embrace construction organizations' contributions to the growing green building movement.

The greening of construction organizations

If construction organizations are to maximize their contributions to green building projects, they must shift their paradigm – away from a fragmented and bid package perspective towards a more holistic and integrated view of projects. The inextricable relationships between water, site, energy and indoor environmental quality issues must be woven into estimating and planning processes, subcontractor education and overall business practices. Some organizations will make this shift voluntarily. Others will only do it when forced by competition. It has already become clear that a construction company's environmental policy is an important way to differentiate itself to owners seeking construction services on green building projects.

Several progressive builders stated that their current efforts in embracing green building at the company level were spurred by positive experiences on their first green building projects. The James G. Davis Construction Corporation is an excellent example. Success in the greening of Davis came from within, through pooling the experience of those in the organization who had an interest, if not a passion, for environmental issues. As in any transitional processes, executive-level support of these initiatives played a key role in embracing green construction as an organization. The goal at Davis is now to leap beyond a project-based response to green buildings, to a more complete approach to environmental management.

Conclusions

Construction organizations clearly have both the potential *and the responsibility* to enhance green building project teams through the fundamental tools of the trade, from value engineering to material procurement to subcontractor communications and pricing. One consistency identified in case study research is that this potential cannot be fully realized unless construction organizations are included on the team during design.

Broad change is hindered by the fact that green building efforts are largely being led by the design profession – the segment of the industry which is still most resistant to integrated teams that include the construction organizations. Perceived as a threat to the design process, many design professionals are most comfortable when contractors are relegated to a low-price commodity on a building project rather than a valuable service provider to a project team.

In the scramble to implement new metrics like the LEED rating system, it has become clear that they will need to evolve. More guidance is needed in defining the contracting methods, organizational structures and services that *enable* green buildings. For example, the LEED system recognizes inclusion of a LEED accredited professional but does little to encourage integrated teams formed through design-build contracting and design-assist services by construction firms.

As more construction organizations gain design-build experience on green building projects, they will be better equipped to align themselves and develop preconstruction services that will enhance the green design process. Also, increased use of *performance-based* project requirements that include more direct construction related elements such as pollution prevention and resource conservation measures, lean thinking in sitework and pre-assembly techniques, and the education of subcontractors and vendors will provide creative incentive programmes that would "fund" a part of this learning curve. Competition could then work to move the US construction industry forward towards a better definition of green *construction*.

One truth is clear. Just as the idea of sustainability broadly defines the relevant environmental costs, the teams whose job is to achieve sustainability in the construction industry must also be broadly defined to include all players in the process.

David Riley will make a presentation on this subject at the CIB 2003 International Conference on Smart and Sustainable Built Environment (SASBE2003) on 19-21 November 2003 in Brisbane, Australia (www.sasbe2003.qut.com/).

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Sustainable construction: a Swedish company's approach

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Skanska is the world's second largest construction company. It builds family homes, commercial buildings (e.g. offices, shopping malls and hotels) and transportation infrastructure including roads, tunnels and bridges. Our products and services impact the lives of many people in developed and developing countries. They also impact people around building sites (e.g. due to heavy traffic and generation of noise and dust).

In 2002 Skanska had 76,000 employees and created employment at over 10,000 project sites around the world. We have to reduce our workforce when we finish a project; this is the nature of the construction business, and an important responsibility.

Why is sustainability important for Skanska?

Skanska has incorporated the notion of sustainability in its business for three main reasons:

- to strengthen our brand;
- for risk management;
- to benefit current and future employees.

Many of our most important clients are actively engaged in addressing sustainability issues, and they expect nothing less from their contractor. Managing environmental and social risks is a key element of our sustainability approach – and not only from a sustainability perspective. It is just plain good business to minimize and manage risks. Accidents and poor performance can have direct negative financial impacts, e.g. through falling share prices, higher insurance premiums, declining project profitability, and increasing costs of crisis management and mitigation measures.

Sustainable development is a key element of our objective to be an attractive employer. Employees want to work for a company they are proud of, and with whose values they can identify. Skanska wants to be competitive in the global marketplace for many years to come, so we must be able to keep and recruit the best employees.

Skanska's sustainability efforts have received external recognition. It has been listed by the Dow Jones Sustainability Indexes for the fourth consecutive year, as well as by a number of other registers for socially responsible investing. Skanska comes first on the Fortune 2003 list of Most Admired Companies in the engineering and construction category, and it is Europe's third most admired company in all categories. Skanska also participates in the UN Global Compact.

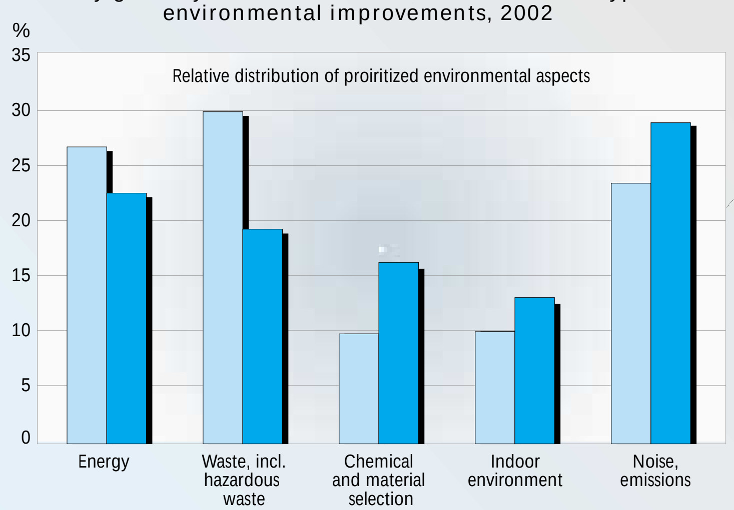
Skanska's corporate code of conduct

In February 2002 Skanska adopted a corporate code of conduct establishing a level of performance for our global operations with respect to employee relations, human rights, business ethics, stakeholder relations and the environment. The code of conduct reflects and refers to a number of UN, ILO and OECD agreements. It is the most tangible umbrella instrument for our implementation of sustainable development. The code of conduct, developed in cooperation with all our Business Units, has been translated and is available in the languages of our home markets (see www.skanska.com/sustainability).

More sustainable construction

As the World Commission on Environment and Development (the Brundtland Commission) noted in 1987 in its report *Our Common Future*, "sustainable development is not a fixed state of harmony, but rather a process of change." For us this means, practically speaking, that we have not defined what sustainable construction is, but an approach to knowing what is *more* sustainable – thereby managing a process of continual improvement. As a global company operating at the local level, we make progress most effectively in small practical steps. These small steps add up to leaps in improved overall performance. The most significant example of this approach is that today Skanska is the first global contractor all of whose units are ISO 14001 certified.

Figure 1
Priority given by Skanska and its clients to different types of environmental improvements, 2002



Skanska has assumed a key role in the construction vs. sustainable development debate. One reason for this is our involvement in a major environmental mishap in 1997, when toxic substances leaked from a tunnel building project at Halland Ridge in southern Sweden. In addition, Skanska has taken an active stance on priority issues such as major hydropower projects and related social and environmental impacts. Skanska decided to withdraw from some major hydropower projects at the end of the 1990s, and to join the World Commission on Dams in 1998 to take part in its assessment of dam building practices.

Skanska is currently gathering information on projects that have shown particularly interesting results related to more sustainable construction. Two such cases, which have been submitted to the UN Global Compact, are bridge building in Honduras and a hydropower project in Sri Lanka.

Honduras

Our activities have included special efforts to work with local communities and raise the bar on environmental management at projects in the developing world. One of the clearest examples has been in Honduras. Skanska was commissioned by the Swedish International Development Cooperation Agency to build 11 bridges and 5 kilometres of road in that country following Hurricane Mitch in 1998. We began by rebuilding infrastructure in some of the worst hit areas. The project delivered most bridges several months ahead of schedule; the key reason identified was effective cooperation and mutual respect between Skanska staff and local Honduran workers. Providing good and clean working conditions resulted in low staff turnover. Skilled and motivated workers do a better job, have fewer accidents, need less supervision and make better use of materials, vehicles and equipment. Communities affected by the construction work were consulted, and some local suppliers were supported with quality and environmental management. Even small initiatives like providing bank accounts for all employees can be important (this helped reduce the number of robberies on pay day).

Sri Lanka

Skanska was commissioned by the Ceylon Electricity Board to build a small "run of the river" dam for power generation in the Kukule Ganga river 70 kilometres southeast of Colombo, the capital of Sri Lanka. Skanska's involvement in the Kukule Ganga hydropower project (HPP) started in June 1999 and ended in April 2003. It mainly entailed tunnel blasting and concreting. Once construction work is completed, a certain amount of water will continue to be released to the original river channel to protect river fauna. Most of the water, however, will be diverted from the river channel, led through a long mountain tunnel to two turbines, and then discharged back to the river channel.

Surrounding the project is the Sinharaja Forest Reserve, a UNESCO World Heritage Site, which is one of Sri Lanka's last untouched rainforests. This area is rich in biodiversity and highly vulnerable to human disturbance. Farmers in the area cultivate rubber and tea.

Skanska's work at Kukule Ganga HPP is pioneering, in the sense that this is the first international waterpower project completed within the framework of the ISO 140001 certified environmental management system, which covers a number of practical issues and activities such as waste management and control of chemical products. The project has established new practices and served as a pilot for other projects. It has been externally evaluated by the Stockholm School of Economics for the UN Global Compact Learning Forum.

Healthy buildings

In 2002 Skanska took the initiative to address moisture and mould in the construction sector in a special project. This is not a new problem for buildings in regions where temperature and moisture are at a level that allows mould to grow. Already in the 1970s, "sick building syndrome" was recognized as a health issue. Mould is one of the most important air quality issues. Related health risks are allergic reactions and respiratory infection. In the project (ending in 2003) Skanska examines options to further minimize risks associated with mould by assessing and developing construction methods and material use.

Environmental performance

Skanska implements many projects whose environmental standards are beyond legal requirements. A yearly analysis of all major construction projects worth over USD 1 million indicates that Skanska and its clients are gradually raising environmental performance standards. Skanska's analysis of order bookings in 2002 shows that 667 large construction projects representing about 45% of total order value, were being implemented with higher environmental standards than legally required. In close cooperation with the client, we assess options for improved environmental performance, costs and benefits of alternative designs or building materials, and costs related to operation and maintenance. In this way we aim to influence environmental performance throughout the value chain. In particular, our Build-Operate-Transfer projects provide excellent opportunities to aim for improvements starting at the design stage, during construction, and while operating and maintaining infrastructure and buildings.

Evaluation of our environmental efforts indicates that the most common priorities for Skanska and its clients are energy efficiency, waste management, and local environmental impacts such as noise, dust and emissions to water and air. Figure 1 shows the relative distribution of Skanska and client priorities for environmental improvements in 2002. Skanska gave highest priority to waste, including hazardous waste (30%). Clients gave highest priority to noise and emissions (29%).

The most important threat to the global environment is climate change associated with greenhouse gas emissions to the atmosphere. The most important cause of these emissions is use of fossil fuels. The construction sector therefore faces a major challenge since around one-third of the energy used by humans is related to buildings and their utilization. A large proportion of this energy use can be avoided. Given today's technology, Skanska has shown that it is possible to improve energy efficiency by over 30% in new construction, for example by using adequate insulation, high performance windows with tripple glazing, and efficient ventilation systems with heat recovery.

Many hazardous substances are used in the construction sector. To reduce use of the most hazardous, several Business Units have developed their own "black" and "grey" lists of substances not to be used, or to be phased out. One challenge is to obtain access to relevant information from suppliers of chemical products.

Skanska has published its Sustainability Report for 2002, which presents the company's economic, social and environmental performance. For copies, contact www.skanska.com or axel.wenblad@skanska.se.

Social aspects of sustainable construction: an ILO perspective

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Summary

This article examines the social aspects of sustainable construction, particularly in the context of developing countries. A socially responsible construction industry is one that enhances the positive aspects of employment in construction while protecting the workforce from negative ones. This requires respect for labour standards, as set out in ILO Conventions and national legislation. Voluntary initiatives have made a positive contribution, but serious progress will require everyone to play by the same rules. Concerted action by all stakeholders is needed to bring this about. A new "Socially Responsible Construction Investment" initiative is being launched by the ILO. It will bring together representatives of government, employers, workers and other major construction sector stakeholders, with the aim of developing a strategy and action plan for improving implementation of key labour standards in construction projects, as well as promoting productive employment in the construction sector.

Résumé

L'article s'intéresse aux aspects sociaux du développement durable du secteur du bâtiment, en particulier dans le contexte des pays en développement. Un secteur du bâtiment socialement responsable se doit de renforcer les aspects positifs de l'emploi dans le bâtiment, tout en protégeant la main-d'œuvre contre ses aspects négatifs. Cela suppose le respect des normes de travail des Conventions de l'OIT et des législations nationales. Si les initiatives volontaires ont eu un effet positif, pour réaliser des progrès significatifs il faut que tout le monde respecte les mêmes règles du jeu. L'action concertée de tous les acteurs est nécessaire pour y parvenir. L'OIT est en train de lancer une nouvelle initiative d'" Investissement socialement responsable dans le bâtiment ". Elle réunira des représentants de gouvernement, des employeurs, des ouvriers et autres acteurs majeurs du secteur du bâtiment dans le but d'élaborer une stratégie et un plan d'action pour une meilleure mise en œuvre des principales normes de travail dans les projets de construction, mais aussi pour promouvoir un travail productif dans le bâtiment.

Resumen

El artículo examina los aspectos sociales de la construcción sostenible, particularmente en el contexto de los países en desarrollo. La industria de la construcción que se preocupa por el bienestar social realza los aspectos positivos del empleo en la construcción y al mismo tiempo protege a los trabajadores de sus aspectos negativos. Para ello, hay que observar las normas de trabajo establecidas por las convenciones de la OIT y las leyes de cada país. Varias iniciativas voluntarias han aportado una contribución positiva, pero el verdadero progreso requiere que todos respeten las mismas reglas, y para que esto ocurra se necesita una acción coordinada de todas las partes interesadas. La OIT prepara el lanzamiento de una nueva iniciativa para invertir en la construcción de manera responsable para la sociedad. La iniciativa reunirá representantes del gobierno, patronos, trabajadores y otras partes interesadas del sector de la construcción para desarrollar una estrategia y un plan de acción que permitan mejorar la implementación de normas de trabajo clave en proyectos de construcción y promover el empleo productivo en el sector de la construcción.

It is generally agreed that sustainable development has three pillars: environmental, economic and social. Environmental sustainability is now broadly understood, and much attention has focused in recent years on economic sustainability. However, the concept of social *sustainability* is much more difficult to grasp. *Responsibility* seems to make more sense in this context than *sustainability*. Indeed, many companies are adopting the principles of Corporate Social Responsibility (CSR). Yet there is still little agreement as to what this actually means in practice.

As a starting point, it might be assumed that social responsibility is about minimizing the negative and maximizing the positive effects economic activity has on people and society. Broadly, economic activity impacts on society in three ways. First, there is the impact on those involved in the activity itself, notably the workforce. Second, there is the impact on the local community where the activity takes place. Third, there may also be social implications for the wider global community.

The relative importance of these impacts varies with the kind of activity. In the case of construction, it may be assumed that global social impacts are minimal (although not entirely absent, due to international migration of labour for work in this sector). The impact on local communities can be quite significant. However, the biggest share of this impact stems from the investment decisions taken up-stream of the industry itself. With very few exceptions, the construction industry responds to demands placed on it by investors, as opposed to playing a major role in the investment decision-making process.

Of the decisions taken within the remit of the construction industry, the major social impact is undoubtedly on the workforce. Hence, a socially responsible construction industry might be defined as one that enhances the positive aspects of employment in the industry and protects its workforce from negative ones.

It is that feature of social responsibility with which this article is concerned. The focus of attention is the developing countries, where three-quarters of the world's estimated 111 million construction workers are found (ILO, 2001a).

The reality of work in construction

On the positive side, the construction industry offers much needed employment for a large number of the world's poorest people. In developing countries construction work provides a traditional point of entry to the labour market for migrant workers from the countryside. A job in construction is often the only alternative to farm labour for those who do not have much education or skill. It has special importance for the landless. Safeguarding such employment opportunities must be high on the social agenda of poor countries with surplus labour. Responsible employers will guard against premature mechanization of tasks that can be undertaken by labourers – as the example from India in the box on the next page demonstrates.

However, there are many negative aspects to work in construction. The industry is notorious as a dangerous place to work. Data from a number of developed countries show that between 20 and 40% of all occupational fatalities occur in the construction sector. This means construction workers are three to four times more likely to die from accidents at work than other workers (López-Valcárcel, 2001). Many more die from occupational diseases arising from past exposure to dangerous substances such as asbestos. In the developing world the risks associated with construction work are undoubtedly much higher (available data

Two examples of social responsibility from India

A voluntary agreement to preserve jobs

In India women undertake most of the tasks involved in mixing and laying concrete. The recent introduction of ready-mix concrete by a large construction company in Chennai has thrown many women out of work. It is also threatening the jobs and livelihoods of many more. After months of protests and demonstrations, the company has voluntarily agreed to restrict the use of ready-mix concrete to large structures.

Using contracts to enhance labour standards and the environment[1]

Engineers India Ltd. is a large public sector consultancy operating chiefly in the oil and gas sector. As a consulting engineering company, it is responsible for inviting tenders and quotations from contractors, awarding contracts, and monitoring progress and compliance with contract conditions.

The general and specific conditions of contract are agreed with each client. Under the leadership of Anil Lyall, the company is carrying out systematic efforts to make these conditions much clearer and more visible in the area of labour standards and the environment. Detailed specifications have been developed for health and safety provisions. The contractor's obligations in this and other areas are spelled out in simple and unambiguous terms. Proper inspection must then take place to ensure that all obligations are met.

Anil Lyall believes that engineers are well placed to carry out these inspections during their regular visits to sites. The conclusion of this work is that considerable improvement is feasible in the employment of labour by contractors on major national projects.

1. Examples from the Global Compact Database.

would suggest from three to six times higher). Yet the causes of construction accidents are well known, and almost all are preventable.

Construction work in developing countries is not only unnecessarily dangerous, it is badly paid and insecure. The majority of workers are recruited through intermediaries or labour agents on a short-term (often daily) basis and dismissed when they are no longer required. They do not receive holiday pay, sick leave, health care, pensions or other benefits. They work long hours and may be forced to work overtime without additional payment (which may be interpreted as a form of forced labour). Wages paid are often below the national minimum and inadequate to feed the workers, let alone their families. Frequently a part of the wage is withheld, as the burden of the contractor's retention (the part of the contract sum retained by the client against default by the contractor, usually 10%) is passed on to the workforce (ILO, 2001a).

These appalling terms and conditions of work owe their persistence, at least in part, to the extensive practice of "outsourcing" labour requirements through labour contractors – a practice that creates divisions within the workforce and prevents the workers from uniting to defend their rights. There is also outright hostility from employers and their agents to unionisation. Workers who participate in union action are often victimized. Trade union density in construction is less than 1% in some countries (ILO, 2001a).

Discrimination in wages and working conditions between different groups is also rife. Women suffer a double form of discrimination in the countries of South Asia, where they constitute up to half the construction workforce. They are only allowed to perform tasks classified as unskilled, and they receive lower wages than men undertaking similar tasks (ILO, 2001a).

Labour standards

Such practices contravene the "core" labour standards of the International Labour Organization (ILO) – the United Nations agency with global responsibility for work, employment and labour issues. The core standards of the ILO, embodied in its 1998 Declaration of Fundamental Principles and Rights at Work, are binding on all member states. They embrace four basic principles of employment:

- ◆ Employment should be freely chosen (no forced labour);
- ◆ There should be strict limitations on employment of children;
- ◆ There should be equality in the terms and conditions of employment;
- ◆ Workers and employers have the right to organize and bargain collectively.

These four principles are also included in the UN Global Compact and are widely regarded as fundamental human rights. Social responsibility requires that they be observed by the construction industry.

While the core standards apply to all sectors of economic activity, other standards are specific to construction. Most important are Convention 167 (1988), "Safety and Health in Construction", and Convention 94, the "Labour Clauses (Public Contracts) Convention". These Conventions, with the accompanying Recommendations and Codes of Practice, set out basic principles that

Key principles of ILO Convention 167 concerning safety and health in construction

- There should be cooperation between employers and workers in order to promote safety and health at construction sites.
- The most representative organizations of employers and workers shall be consulted on the measures to be taken and all have a duty to comply.
- The principal contractor is responsible for coordinating the prescribed safety and health measures and for ensuring compliance with such measures.
- Personal protective equipment and clothing shall be provided and maintained by the employer without cost to the workers: employers must also provide first aid, drinking water and separate sanitary and washing facilities.
- Workers must be informed of potential safety and health hazards to which they may be exposed and trained in their prevention and control.
- Workers have the right to remove themselves from imminent danger and the duty to inform the supervisor.
- Those concerned with design and planning of a project also have a duty to consider the health and safety of construction workers.

The construction industry is a dangerous place to work

need to be observed to ensure the health and safety of construction workers and to protect those working on public contracts.

While these Conventions are only binding on the countries that have ratified them, most countries (even developing ones) have national legislation in place that is broadly in conformity with the principles of these and other ILO Conventions designed to offer some protection to the workforce.

Social responsibility clearly requires observance by the construction industry of workers' rights enshrined in the ILO Declaration, as well as in other ILO Conventions and national legislation. Most important are the rights of workers to join organizations of their choice, to have a safe place of work, and to be paid their wages on time and in full.

The importance and limitations of voluntary action

The architecture, engineering and construction community can do much to promote these principles in the developing world. International contractors and consultants – predominantly firms from developed countries – implement a high proportion of construction projects in developing countries. When working in these countries, they should commit themselves to socially responsible business practices that protect and promote workers' rights.

A number of international companies have already made such a commitment. Germany's Hochtief, ranked as the worlds largest international contractor, has signed an agreement with the International Federation of Building and Woodworkers (IFBWW), a global trade union federation representing 11 million construction workers in 124 countries. The agreement commits Hochtief to promote fair pay and decent working conditions. Hochtief also requires compliance by all its subcontractors and joint venture partners. Similar agreements have been signed between IFBWW and other international contractors, notably Sweden's Skanska and Ballast Nedam of the Netherlands. Although such agreements are entirely voluntary, some monitoring procedures are in place to ensure compliance and the results so far have been positive.

There is no doubt that the "best practices" of international companies operating in a developing country can have a powerful demonstration effect, but the large international contractors that sign such agreements (most of them European) handle only a small proportion of construction projects worldwide. The vast majority of large companies, and the long tail of small and micro enterprises that characterize the construction industry around the world, are very far from signing up to such principles and even further from implementing them. The result is a few small islands of good practice in a sea of bad.

It is also of concern that social responsibility is not costless. While it is possible that the additional costs incurred by employers through observing good labour practices may be recouped in the longer term through productivity gains, in the short term there is a cost involved. Hence, firms that abide by internationally recognized standards are penalized when others ignore them. Competition among international contractors for work in developing countries is cut-throat, with many new entrants to the field, and there is ample evidence that "good employers" are no longer winning contracts. If socially responsible behaviour is to survive and prosper, there has to be a "level playing field".

Governments have a heavy responsibility for the creation of this level playing field through adopting and enforcing appropriate legislation. This is not an easy task. The difficulties inherent in inspecting a large number of small and scattered construction sites are well known. These difficulties are compounded in developing countries by lack of resources for labour inspection. Industrialized countries now rely heavily on "self-regulation" to ensure the safety and health of the workforce, which involves development of management systems and, in particular, the establishment of safety committees with representation from the workforce. However, this approach is also difficult to implement in developing countries, where workers are unorganized and unaware of their rights and employers are ignorant concerning their obligations.

Making progress towards social responsibility

Responsible employers share a common interest with workers' organizations and with governments in promoting widespread respect for labour standards, so as to ensure a level playing field. They also recognize governments' inability to bring this about through enforcement of labour legislation through inspection. In the negotiated conclusions to a tripartite meeting convened by the ILO in December 2001, it was proposed that governments (as major clients of the construction industry) might use their procurement procedures to ensure that contractors and subcontractors comply with national legislation, including health and safety legislation (ILO, 2001b). It was also suggested that these obligations on the contractor could be written into contracts as "labour clauses". For those not fulfilling their obligations, there would be an immediate sanction in the form of exclusion from tender lists.

The meeting went further, proposing that not only governments but also the international financing institutions that fund much public construction should "encourage socially responsible business practices that promote and protect workers rights in accordance with the ILO Declaration on Fundamental Principles and Rights at Work" (ILO, 2001b, p. 27). The ILO was asked to provide a platform for social dialogue and for discussions with financial institutions such as the World Bank to help bring this about. Joint pressure on the World Bank – from the ILO and the industry partners at global level (Confederation of International Contractors Associations (CICA) and the IFBWW) – to strengthen the labour clauses in contracts and upgrade them from "recommended" to "mandatory" has so far had little success. The Bank is reluctant to commit itself for fear it will not be able to monitor the contractor's compliance.

The UK Department for International Development (UK/DFID) has recently made a significant breakthrough in this respect. Through careful research and action in a number of developing countries, the Social Aspects of Construction (SAC) project has not only shown the possibility of inserting labour clauses into a variety of different types of construction contract, but has also demonstrated how contract compliance can be monitored and enforced from within, by the whole project team, during the normal inspection process (Ladbury et al., 2003). A further innovation demonstrated by the project is the calculation of additional costs of compliance and their inclusion as preliminary cost items in the Bill of Quantities. In this way the cost of observing labour standards is taken out of competition.

Details of the DFID/SAC approach and how to apply it have been set out in a source book available on the Internet (www.lboro.ac.uk/wedc/projects/sac/index.htm). One great advantage of this approach is that it can be tested and applied on any scale, from a single contract to a whole country programme. In the case of commercial contracts, the initiative to do so may come from the donor, the client or the client's representatives – the consultants of the construction industry (architects, engineers and quantity surveyors).

The support and involvement of consultants in this approach would seem to be particularly important, as they will have additional responsibilities in the pre-bidding and bidding processes as well as in monitoring contract compliance. Supervising architects and engineers make frequent visits to construction sites. They are well placed to observe working and living conditions at these sites. Many have already registered concern at the widespread abuse of labour rights. Some are already taking action on their own initiative. The potential that the DFID/SAC approach presents for greater involvement of the consulting industry in social responsibility issues is therefore generally to be welcomed.

The ILO is now launching a new initiative to promote "Socially Responsible Construction Investment". The initiative will bring together representatives of government, employers and workers with other major stakeholders in the construction sector. The aim will be to agree a strategy and develop an action plan to improve implementation of key labour standards in construction projects, as well as to promote productive employment in the construction sector.

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Promoting innovation in construction SMEs: an EU case study

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Summary

Construction is one of the oldest and most important industries. It provides shelter and a physical framework or basis for many human activities. It enables us to live, socialize and exploit our environment – in short, to realize our potential. However, it also constrains our potential in that it imposes limits on enterprise, innovation, productivity and the ability to sustain growth by tackling poverty, social exclusion and climate change. This article describes the main features of the EU construction sector and addresses some problems related to promoting sustainable construction. The basic needs of construction SMEs in particular are described, as well as measures being taken to address these needs. Europe and developed countries on other continents may have much to learn from the development approach and support systems of projects in developing countries.

Résumé

Le bâtiment est l'un des secteurs d'activité les plus anciens et les plus importants. Il procure un refuge et un cadre ou une base physique à de nombreuses activités humaines. Il nous permet de vivre, d'avoir des relations sociales et d'exploiter notre environnement, bref de réaliser notre potentiel. Mais il exerce aussi une contrainte sur notre potentiel du fait qu'il impose des limites à l'esprit d'entreprise, à l'innovation, à la productivité et à notre capacité de lutter contre la pauvreté, l'exclusion sociale et le changement climatique. L'article décrit les principales caractéristiques du secteur du bâtiment dans l'UE et aborde quelques-uns des problèmes qui freinent le développement durable du secteur. Il évoque en particulier les besoins fondamentaux des PME du bâtiment, ainsi que les mesures actuellement prises pour y répondre. L'Europe et les pays développés d'autres continents auraient peut-être beaucoup à apprendre des mécanismes de développement et de soutien des projets des pays en développement.

Resumen

La construcción es una de nuestras industrias más antiguas y una de las más importantes. Provee protección y una base o contexto físico para muchas actividades del ser humano. Nos permite vivir, socializar y aprovechar nuestro medio ambiente: nos permite realizar nuestro potencial. Sin embargo, también limita nuestro potencial ya que impone límites a las empresas, la innovación, la productividad y a nuestra capacidad de combatir la pobreza, la exclusión social y el cambio climático. El artículo describe las características principales del sector de la construcción de la Unión Europea y trata sobre algunos problemas que conlleva el fomento de la construcción sostenible. Describe en particular las necesidades básicas de las PYMES de la construcción, así como las medidas que se toman para satisfacer dichas necesidades. Europa y los países desarrollados en otros continentes tienen mucho que aprender del enfoque que se le da al desarrollo y a sistemas de apoyo de proyectos en los países en desarrollo.

Construction is one of the EU's most important industries. It is responsible for production, assembly, disassembly, rehabilitation and maintenance of residential buildings, non-residential buildings and the physical infrastructure, which provide the framework or basis for many if not all of our activities. It enables – and is driven by – structural changes in the economy, as indicated by growth in non-residential construction (e.g. offices, commercial buildings) and the decline of civil engineering since the mid-1990s.

Construction is a major factor in the EU's drive to raise the level of potential (and sustainable) output. Concerning the latter, the construction sector's impact on society and the environment should not be overlooked. The process itself draws on the environment for its resources and (via its output) contributes significantly to environmental pollution. Its activities and output can and do contribute significantly to the existence and resolution of major social problems such as immigration, social divisions and poverty.

Construction is an important activity in its own right, providing income and employment to many people. Its core activity (on-site work by specialist builders, including assembly of main frames and building envelopes, installation of electricity services and technical equipment, finishing work) accounts for approximately 5% of economic activity in the EU and employs 7% of the EU's workforce.[1]

This activity is only part of the construction process. The boundaries of the construction sector are debatable, and the process clearly involves many activities that are not carried out by building firms and therefore not accounted for by traditional measures concerned with construction activity. These activities include design (architectural work, engineering, surveying), project management, the manufacture and distribution of materials, components and equipment, extraction and distribution of aggregates, sand and gravel, research and development, and various real estate activities.

Physical and social conditions

Construction and its final outputs are subject to a number of unique physical and interrelated social conditions. The product is spatially and temporally fixed, and a large proportion of construction work takes place on-site – where it is subject to the vagaries of nature. It is further constrained by the nature of the product (or needs of the client) and the level of technical development, in terms of the materials, components, equipment and labour available to meet those needs.

On-site construction is mainly undertaken by small local firms. There are relatively few large firms and relatively little export activity (i.e. little international trade), although in the case of large projects intra- and extra-export activity has been increasing within the EU. The vast majority of construction firms (90%) are small to medium-sized; of these, 93% are micro firms (fewer than ten employees). These firms employ 50% of the total construction workforce. Some 55% have no employees (workers are self-employed); roughly 25% of the labour force is self-employed.

This industry is labour intensive. Labour is mostly undertaken by males. The level of education is lower than average although this is highly spread, ranging from tertiary (engineers) to lower secondary (low-skilled labourers). Employment is relatively insecure, with 19% of construction workers on temporary contracts.

Of course there is no general model for the construction process. Rather, there are a many construction processes that vary according to the type of project: residential, non-residential or civil. Differences are associated with the organization of the project and the general organization of the industry (e.g. contrast the organization of speculative house-building with the relatively complex forms of contracting used to organize many non-residential projects). Processes vary according to the activities directly associated with implementation or execution of specific building projects, such as design and assembly. They also vary with the activities indirectly associated with the process, such as prefabrication. Differences may arise based on the unique geographical and historical circumstances that exist in different countries and regions.

Construction processes also change. They may evolve according to economic and social developments within and outside the industry. In the UK, for example, conflicts between large-scale capitalist (i.e. for-profit) building firms and their clients, workforces, subcontractors and design professionals have resulted in a significant shift towards market-based organization of construction in the form of pyramidal subcontracting (i.e. market-based division of labour, with firms becoming highly specialized). The main contractor, usually a large firm, manages the project or at least construction work. Subcontractors provide work to specialist firms that undertake actual construction work and subcontract some work to other firms).

This has been accompanied by a considerable reduction in the management role of architects, abolition of fee scales for professional services, new techniques in construction management (e.g. fast-tracking and design-and-build), increased use of competitive tendering for public sector contracts, increased use of various professional services (tendering, surveying, legal), specialization in core activities and associated outsourcing of equipment, materials and components, and (more recently) informal vertical and horizontal integration as a means of better managing risks associated with the contracting system.

The CONSTRINNONET project

The physical and social conditions of construction also have an important effect on the behaviour and, therefore, the needs of individual construction firms. In the UK, large capitalist building firms have accumulated capital by managing an evolving portfolio of projects and using the contracting system to source design, construction, materials, components and equipment. Their individual needs are predominantly managerial. By contrast, smaller specialist subcontractors compete for work in a highly competitive environment. They need to be flexible operationally in terms of what they do and how they do it, which requires specific operational and managerial skills. Moreover, if they are to exercise more control over their business environment and better manage their workload and cash flow as a potential basis for growth, they require other managerial skills including that of managing networks of clients, suppliers and collaborators through partnerships, joint ventures, framework agreements and other organizational innovations.

The issue of needs is important to policy makers throughout the EU. It helps answer serious questions about the performance of construction – i.e. about the quality of products, project delays, cost overruns, productivity, environmental impacts, social impacts and general economic impacts. Construction firms will be relied upon to take action to remedy those problems.

However, the interests of the EU extend beyond those of construction firms to the "collective interests" of the industry, economy, society and environment. The goal of the EU's Lisbon strategy and the ultimate goal of EU industrial policy is to make the EU "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable growth and more and better jobs and greater social cohesion" by 2010.

From that perspective, construction firms need to provide better value-for-money for their immediate clients and for society in general. This can only be done with some form of outside state-sponsored intervention. The question is: how should the state intervene?

Industrial policy is one of the main policy areas affecting construction. EU industrial policy has three main objectives: knowledge, innovation and entrepreneurship. This approach involves the framework conditions within which industry can find its own solutions. These can be developed according to the specific needs and characteristics of individual sectors, regions and countries together with other policies such as competition, regional, research and development, education, trade and sustainable development.

Against this backdrop, a project is currently being undertaken to promote innovation in small and medium-sized construction enterprises. The CONSTRINNONET project is funded by the EU as part of its Fifth Framework Programme for RTD (research, technological development and demonstration).[2] This project has two main objectives: to explain the process of innovation in construction SMEs; and to show how national and EU-wide business support programmes can be designed, organized and/or implemented to promote successful innovation in construction SMEs. The 36-month project will be completed in May 2004.

Innovation has a dual meaning. It can refer to a process and/or to the outcome of the process, i.e. "successful innovation". According to the EU, innovation involves activities intended to result or actually resulting in the use of new or improved products or processes. This includes creation, development and implementation of new knowledge. The knowledge can be technological or organizational. It can be new to the world, the industry or the firm. It involves development and diffusion of new science-based technologies and the packaging or fusion of existing technologies. It also involves organizational change, which is often combined with technological innovation.[3]

The construction industry has a long history of successful innovation. It has used new or improved materials, components, tools and activities, and new ways of organizing projects. Recent examples of process innovations include fast-track construction (simultaneous production of drawings and of the final building), design-and-build (e.g. in the case of small, standardized or proprietary factories and warehouses), prefabrication, outsourcing of tools, automation (including use of robots), new communications technology (including e-business), and new and improved plant technology (e.g. related to cranes, earth-moving equipment, drills, scaffolding). Recent examples of product innovation include "intelligent" buildings (e.g. incorporating wireless technology), new lighting technology (e.g. fibre-optics), new composites (including technical improvements to concrete and glass, use of recycled plastic and wood), improvements to steel frame technology, and new air-cooling systems.

Innovation in the construction industry

The nature and extent of innovation in construction, like construction itself, is very different from that of other industries. Both depend critically on the physical nature of construction and its social and economic organization. In turn, these conditions depend on specific geographical and historical circumstances. For example, it has been difficult for individual building firms in the UK to gain market advantage over competitors in other countries through technical innovation, especially where this requires large amounts of fixed capital, due to variable exchange conditions and production conditions and the prevalence of sub-contracting. Indeed, most of the UK's larger building firms prefer to outsource workforce, equipment and materials. Similarly, many of the smaller specialist sub-contractors find that it is more cost-effective to outsource materials and components if not equipment. A fairly clear market-based division has therefore arisen between direct construction activities on one hand and production of building materials and tools on the other.

The economics of the industry in the UK and elsewhere mean that there is relatively little technical innovation in construction. Manufacturers must create and develop knowledge, either themselves or in partnership with specialist R&D organizations, which they must then sell to construction firms and design professionals. This problem (selling materials, components and equipment) has in fact led to several organizational and technical innovations. These are mostly organizational innovations. Some are ancillary technical innovations or innovations in the exchange sphere (e.g. e-business). Technical innovations in the production sphere (e.g. materials and tools) appear to be shaped by, for example, standardization and inhibited (relatively little) by the diversion of manufacturing and indeed the ownership and maintenance of equipment from core construction (e.g. materials producers that operate as specialist sub-contractors or form alliances with specialist subcontractors; e-business; standardization of materials and components).

The ability to sell the knowledge often requires the development of operative skills, which individual construction firms are reluctant to finance, and the capacity to take risks, which tends to be lacking among smaller, petty capitalist or petty commodity producers operating in a highly competitive and uncertain environment.

The challenge for government and governmental agencies is to correct these industrial failures: to identify and promote the use of superior production techniques, materials and components; identify and fill skills gaps; and encourage appropriate risk-taking. Or, in other words, to reconcile the interests of individual firms to the collective interests of the industry, economy, society and environment.

But what should be done to help the industry deal with and exploit the externalities and other types of industrial failure that inhibit its willingness and/or ability to create, develop, apply and diffuse knowledge? What should be done to encourage and help SME building firms train their operatives? What should be done to promote organizational change in the design profession? What should be done to help building materials firms and engineers invest in new technology, bearing in mind the nature of the core process of construction? What should be done to promote risk-taking by design and construction SMEs? What should be done to improve the key interfaces a) between universities, research organizations and the industry; and b) within projects and between clients, users, building contractors, designers, manufacturers, and regulators?[4]

The EU, its Member States and its Candidate States have established various mechanisms to promote "successful [sustainable] innovation". They include direct innovation initiatives and indirect knowledge and enterprise initiatives. They also include financial support (subsidies, grants, loans) for individual and collective RTD; technology advice services; coordination mechanisms that raise awareness of, improve access to, and support the use of knowledge; "one-stop shops" or single contact points for innovation support; specific help for seedling companies; various networking initiatives; training programmes; business information for effective decision making; Business Angel networks to improve access to venture capital; and best practice programmes.

Existing mechanisms are predominantly horizontal in nature, with no specific targeting of particular industries or sectors. However, some have been designed to promote successful innovation in construction. There are construction-specific technology advice services (e.g. in Belgium); national construction technology programmes (in Finland); applications of research and innovation programmes to construction (in France); programmes to promote sustainable building (in Greece); construction industry training programmes and various best practice initiatives (in the UK).

Addressing the needs of SMEs

Although there is little hard statistical data on the performance of these initiatives, anecdotal evidence suggests that few address the specific needs of individual construction SMEs. Many are more suitable to the manufacturers of building materials, components and tools, rather than actual construction firms; those that are suited to construction firms, such as the Rethinking Construction programmes in the UK, are usually best suited to large firms. Thus very few construction SMEs are aware of the mechanisms and even fewer make use of them. Many simply do not have the time to make use of these mechanisms or regard the investment as too risky or inappropriate. Many argue that the process of getting financial support, for example, is too bureaucratic and too long, especially for businesses relying on short-term projects, flexibility and a rapid turnover of capital.

The CONSTRINNONET project is seeking to discover how these and other initiatives can or do promote successful innovation in construction SMEs. Case studies and pilot actions are being developed in each of the seven regions covered by the project. Studies and actions reflect the different characteristics of project partners, the national culture and the prevailing form of innovation system, as well as the perceived needs (individual and collective) of construction and construction-related SMEs in their different regions.

One partner is developing a single entry point system that could give construction and construction related SMEs in its country immediate basic access to EU and national services. Many of the existing single entry point systems are not tailored to fit the needs of construction firms, never mind construction SMEs. And no such system has been designed for construction SMEs there. The process of developing and implementing such a system would provide a test case for its use in other countries and provide valuable data concerning the needs of construction SMEs and the performance of various related business support systems which could be used to produce case studies and develop other ideas for action. It could complement similar but broader initiatives, such as the EU's B2Europe initiative, by actually fitting those initiatives to the needs of construction SMEs or showing how that could be done.[5]

In the UK, the government and its various agencies (e.g. the Small Business Service, Regional Development Agencies, the Construction Industry Training Board, Rethinking Construction, Learning and Skills Councils) are working together in various combinations and with various members of the industry to develop new or improved support programmes for construction SMEs. They have established teams of advisors (e.g. the Manchester Construction Partnership) that work with construction SMEs to identify and source appropriate support, some of which has been designed for those construction SMEs specifically as part of the service. They use existing benchmarking tools to improve the advice they give construction SMEs. They have established regional centers of innovation in construction (e.g. the Centre for Construction Innovation in Manchester and the Centre for Knowledge and Innovation in Building Technologies in Stoke), which offer concentrated support for various construction SMEs.

They also continue to develop strategies to promote specific programmes that have been underutilized by construction SMEs. Most of these initiatives are only recently underway, so it will take time to report on the results. However, the Manchester Construction Partnership has been successful in increasing use of SBS support by construction SMEs.

Another partner is working with a network of construction SMEs, regional development centres and national bodies to promote construction related aspects of sustainable development such as eco-efficient housing and environmental considerations. Other actions by the various partners are planned. They include, among others, a guide to good practice in promoting innovation in construction SMEs and a guide to EU support in this sector that would be written for construction SMEs.

Such guides might include examples of successful innovation, knowledge and/or enterprise initiatives. The initiatives may be regional, national and/or EU-wide. Some may have been designed to support construction or construction-related SMEs. The rest will have been adapted according to specific needs and characteristics of those firms. In either case, the main objective will be to show how governments have promoted innovation in construction SMEs (e.g. cases might explain the needs of the targeted SMEs, how initiatives were designed, adapted and/or applied to fit those needs, and the performance of the initiatives in terms of their efficiency and effectiveness in promoting innovation in construction SMEs). There are other guides to best practice, such as the EU's *Top Class Business Support Services*,[6] but they do not explain the problems of promoting innovation in construction SMEs or actions that have or can be taken to resolve them.

Exchange events have been planned in a number of regions. These events will bring together business support organizations, representatives of construction SMEs, and case SMEs to exchange information about business support. More important, they will provide opportunities for business support organizations to learn from one another and to work together to improve their services to construction SMEs.

Some wider considerations with respect to SME behaviour in other countries might be raised, although the CONSTRINNONET project (dealing primarily with Europe) is only partly through its work. Construction activity, including its associated industrial branches and the SMEs that predominate within it, is clearly present and characterized by similar traits, as outlined previously, in many other countries outside Europe. The project's current involvement in other international study initiatives on innovation in construction point to such a situation. This is not to suggest that blueprint solutions can be applied indiscriminately to constraints facing SMEs in the sector. The very fact that there is a strong cultural element in buildings and construction, together with the localization of activity, warn against such a notion. In addition, systems and structures that support innovation in general are of course very different across countries of the world.

Developing countries are no exception in displaying many of the features and issues related to construction that the project has studied. While some cultural dimensions may predominate, and basic needs for housing and infrastructure take priority over the need for innovation, the sector's SMEs still face corresponding issues (e.g. information, time and skills, contracts). However, there may be more for Europe and the larger developed countries to learn from the development approach and support systems of projects in developing countries. Here there may be further clues to best practice in support of construction SMEs, where effectiveness of programmes and impact measurement are key ingredients.

Notes

1. Eurostat (2000) *Panorama of European Business*. This publication is the source of statistical data cited elsewhere in this article. The classification of construction is part of the NACE Rev. 1 classification of economic activities published by Eurostat.
2. EC-funded project IPS-2000-00002, with University of Salford (UK), Carsa (Spain), Belgian Building Research Institute, Centre Scientifique et Technique du Bâtiment (France), Paragon Ltd. (Estonia), Vilnius Gediminas Technical University (Latvia), VTT (Technical Research Centre of Finland) Building and Transport (Coordinator, Finland).
3. See, for example, *Innovation and Technology Transfer*, February 2003 (special issue), European Trend Chart on Innovation: Reviewing Europe's Progress in 2002.
4. On the problem of organization see, for example, B. Atkin, *Innovation in the Construction Sector*, ECCREDI, 1999, and L. Koskela, How can construction research be organized? An overseas comment on the Fairclough Review, *Building Research and Information* 30:5, 2002, pp. 305-11.
5. For more information on the B2Europe initiative, see European Commission press release IP/03/317 (http://europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc=IP/03/317|0|RAPID&lg=EN).
6. http://europa.eu.int/comm/enterprise/entrepreneurship/support_measures/top-class/bestproc.htm. ◆

Tools for environmental assessment of existing buildings

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Summary
Many countries have adopted environmental assessment methods that can support decision making in building management. Working Group 100 of the International Council for Research and Innovation in Building and Construction (CIB W100) has been reviewing implementation of several such methods. The Australian, Swedish, Norwegian and Canadian tools presented in this article are intended for assessment of existing buildings. The French and Japanese approaches include tools for existing buildings. Strengths and weaknesses of each method are briefly discussed. Most combine self-assessment with some type of external verification (often related to certification), which guarantees quality while allowing the parties most closely involved to work directly with the method. Environmental assessment methods and tools for buildings are being developed and implemented in a growing number of countries. The most recent approaches address environmental issues not only at various design stages but also during building operation.

Résumé
De nombreux pays ont adopté des méthodes d'évaluation environnementale à même d'appuyer le processus décisionnel dans la gestion des bâtiments. Le groupe de travail 100 du Conseil international pour la recherche et l'innovation dans le bâtiment (CIB W100) a fait le point sur la mise en œuvre de plusieurs de ces méthodes. Les outils australiens, suédois, norvégiens et canadiens présentés dans cet article sont destinés à l'évaluation des édifices existants. Ceux de la France et du Japon comportent des outils pour les édifices existants. L'auteur mentionne brièvement les atouts et les points faibles de chaque outil. La plupart combinent une autoévaluation et une certaine forme de contrôle externe (souvent liée à la certification) qui garantit la qualité, tout en permettant aux parties les plus directement concernées d'utiliser directement la méthode. De plus en plus de pays entreprennent d'élaborer et de mettre en œuvre des méthodes et outils d'évaluation environnementale pour le bâtiment. La tendance récente est d'aborder les questions d'environnement non seulement aux diverses étapes de la conception, mais aussi pendant la phase de construction.

Resumen
Muchos países han adoptado métodos de evaluación medioambiental que pueden apoyar la toma de decisiones en la gestión de los edificios. El Grupo de Trabajo 100 del Consejo Internacional para la Investigación e Innovación en Edificios y en la Construcción (CIB W100) ha estudiado la implementación de varios de estos métodos. Las herramientas utilizadas en Australia, Suecia, Noruega y Canadá presentadas en el artículo están destinadas a la evaluación de edificios existentes. Las de Francia y Japón incluyen herramientas para edificios existentes. Los autores reseñan las ventajas y desventajas de cada una de las herramientas. La mayoría combina la autoevaluación con otro tipo de verificación externa (a menudo relacionada con la certificación) que ofrece garantías de calidad y permite que las partes más implicadas trabajen directamente con el método. Cada vez más países desarrollan e implementan métodos y herramientas de evaluación ambiental para edificios. Los enfoques más recientes tratan las cuestiones medioambientales en varias etapas del diseño y también mientras el edificio está en funcionamiento.

CIB W100, the Working Group on Environmental Assessment of Buildings of the Netherlands-based International Council for Research and Innovation in buildings and construction (of which the authors are joint coordinators), recently undertook the updating of a review of environmental assessment methods carried out between 1996 and 1999 under the auspices of the International Energy Agency (IEA). Here we report some of the latest developments.

The IEA project ("Annex 31: Energy-Related Environmental Impact of Buildings") produced an overview of methods and tools in 14 countries. All the countries whose latest approaches are discussed below were part of the Annex 31 group.

The CIB W100 review found that the number of countries developing and implementing environmental assessment methods and tools for buildings is increasing. The latest tools address environmental issues – not only during particular design stages but also in building operation, as the agenda for environmental assessment becomes more targeted to daily design and management decisions.

The first four approaches discussed here are tools intended for assessment of existing buildings. The last two are, in effect, frameworks that include such tools. Most of these tools combine self-assessment with some type of external verification, which is often related to certification. This process guarantees quality while allowing the parties most closely involved to work directly with the method.

The intended users of most environmental assessment tools for buildings are property owners and managers. However, at least two of the methods reviewed below have (or will have) a component for use by tenants and other building users. In general, office buildings and commercial properties form the main target market. At least two of the methods include a version specifically geared for single-family houses; one of them appears to have encountered administrative problems.

NABERS (Australia)

The National Australian Building Environmental Rating System (NABERS) project, begun in 2001, aims to develop Australia's first comprehensive rating system for existing, operational buildings. This system, a pilot version of which was due to be launched in 2003, will be capable of rating both office buildings and homes. Other building types may be added later.

NABERS is being designed as a performance-based rating system measuring a building's actual environmental impact during operation, using real measurements rather than simulations, predictions or estimates. A NABERS assessment will take into account both building and user considerations.

NABERS will be a voluntary rating system, and self-assessment will be possible. However, formal certified ratings will be encouraged, especially where a NABERS rating is to be made public. It will be possible for an assessment to be conducted only once, but it is planned to have ratings made annually to encourage continued improvement.

NABERS assesses only those environmental factors relevant for existing buildings, including energy use, water use, storm water volume and pollution, sewage outfall, site ecology/biodiversity, transport, waste, indoor air quality, comfort and toxic materials.

Strengths
The existing building stock, for which NABERS is designed, is always going to be the vast majority of buildings.

NABERS aims to promote continued improvement in the design profession and in user behaviour.

Because NABERS uses real measurements and is intended to serve as a reporting and performance management tool, it should help bridge the gap between design intention and actual environmental outcomes.

Weaknesses
Because NABERS does not address other phases of a building's life cycle (though it clearly has strong implications for design as well), it must always be seen as just one part of a holistic approach to a sustainable built environment.

Environmental Status (Miljöstatus) (Sweden)

Environmental Status is a system for inspection and assessment of buildings. It covers about 90 environmental aspects, divided into four main groups: indoor environment, outdoor environment, energy, and natural resources. Each aspect is graded on a five-point scale: 5 is "sound throughout" and 1 is "bad." The inspection is primarily visual, but it can include simple measurements of VOCs, formaldehyde, air circulation effectiveness and radon. It may be supplemented by questionnaires and further tests if necessary.

The Association for the Environmental Status of Buildings, grouping about 40 member organizations (mostly building owners), administers the system. The association began developing the Environmental Status Model in 1995. The system went into operation as a practical tool for facility management in April 1997. Version 4 was launched in January 2002.

The results of the environmental inspection are processed as a report, including a series of graphs known as "environmental status roses" (Figure 1).

Some 2000 buildings, totalling around 15 million square metres, have been inspected. About 600 people have been trained and licensed to use the system, which is widely accepted in the real estate sector.

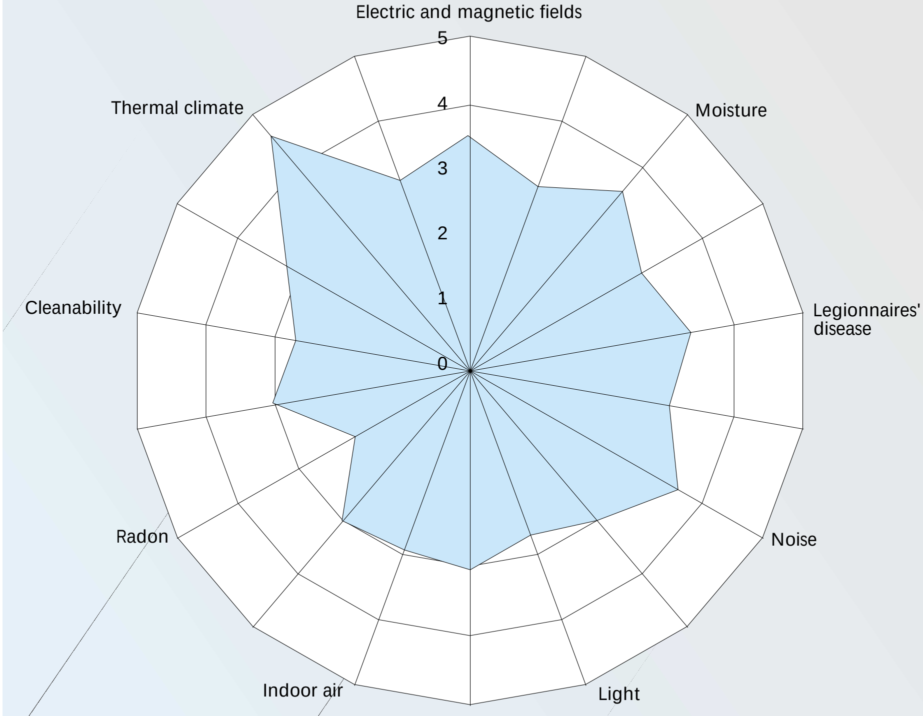
Property owners can use the system as part of the inventory procedure before introducing an environmental management system. Building managers use it to aid in operations and maintenance planning. With the introduction of Version 4, tenants can also now use the system to document their own environmental steps and work with owners on finding solutions (e.g. regarding energy and water use). It is also aimed at financing bodies, insurers and prospective buyers.

Strengths
The system was developed on the basis of member organizations' requirements.

A large member group supports and uses the system.

The method is simple enough to keep costs acceptable, but this simplicity is not at the expense of reliability.

Figure 1
Environmental status (Miljöstatus) system: a rose graph



The larger the environmental rose, the better the environmental status

Weaknesses
None reported.

Ecoprofile (Norway)

Ecoprofile is an official, voluntary environmental classification method for buildings. It is based on the classification of about 80 performance parameters in three areas: external environment, resources, and indoor climate. The parameters describe the building itself as well as maintenance, operation and use. A single index is presented for each of the three areas.

Self-assessment is possible for internal use, but a formal, certified rating is needed if the assessment is to be made public.

Ecoprofile was developed by a group of building owners, experts and researchers to assess existing commercial buildings. Later versions exist for evaluating existing houses and as a planning tool for houses. The method, begun in 1994 and originally called Environmental Profile, was merged with another Norwegian building assessment method and launched in its current form in late 1999.

About 60 official assessments of commercial buildings were carried out in 2000-01. Some 60 houses were evaluated during the assessor training period. About 100 assessors have been trained.

During its two first years the programme was organized and marketed by the EcoBuild programme. Since 2002 the Ecoprofile method has been owned by Byggforsk, the Norwegian Building Research Institute. The method was not marketed in 2002 due to funding limitations, and no buildings were assessed. So far Ecoprofile cannot be said to have been a success.

To establish the method on the market, it may be necessary to change the concept, for example by producing one index instead of three, reducing the number of parameters, and improving the weighting of parameters.

Green Globes (Canada)

Green Globes, an on-line energy and environmental assessment method, is part of the BREEAM/Green Leaf suite of assessment tools for buildings. It uses an interactive, Web-enabled, confidential questionnaire from which it generates a report. Separate versions address operation and management of existing buildings and design of new buildings.

The method is simple. Registered users complete the questionnaire, which seeks to determine how well the building and its management measure up against the best in areas such as energy, water, hazardous materials, waste management and indoor environment. Most questions can be answered "yes" or "no." The process takes about two hours.

Once the questionnaire is completed, an online report is generated highlighting the building's achievements, quantifying its energy performance and greenhouse gas emissions, and recommending areas for improvement, with the order of magnitude of potential cost savings.

In Canada, BREEAM/Green Leaf tools were originally developed for building users, who wanted an affordable, streamlined method. Government organizations, a federation of municipalities, a hotel association and major property management firms have used the tools. A UK version of Green Globes, called GEM, was launched in 2002.

Green Globes is a self-assessment method, used chiefly by property owners and managers. Third-party verification, resulting in certification, is being put in place. Certified buildings will be able to display a plaque publicizing their performance. Certification will also allow comparison of buildings that have had their data verified.

The method's first year of operation was 2002, during which more than 100 users registered for existing building assessments.

Strengths

The Green Globes report uses the same headings recommended for preparing a submission for the Earth Awards administered by the Building Owners and Managers Association. BOMA reported that, as a result:

- ◆ the number of Earth Award submissions doubled from the previous year;
- ◆ entrants said it was easier to prepare submissions, most of which reportedly took less than a week;
- ◆ the quality and appearance of the submissions improved;
- ◆ third-party verification by the BOMA awards committee confirmed the ratings generated by Green Globes;
- ◆ submissions' high level of accuracy indicates that the questions are specific, clear and not open to misinterpretation.

Weaknesses

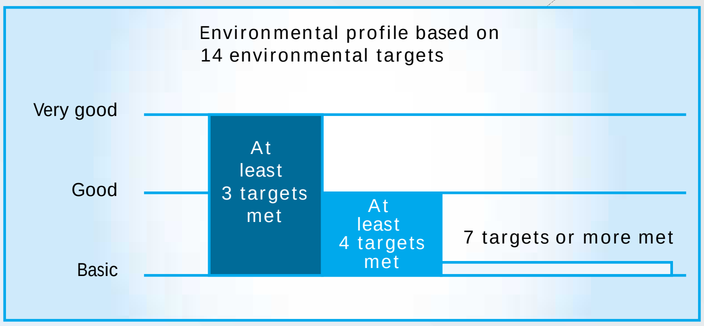
Funding is inadequate, particularly for rapid commercialization.

HQE (France)

HQE is short for *haute qualité environnementale* ("high environmental quality"). It is a national certification system for non-residential buildings such as offices, schools, hotels and shopping centres. The name recently became a registered trademark. In 2002 the method entered a two-year test period, during which it is being applied to controlled pilot projects. It is then expected to become official after formal approval by an ad hoc committee.

The system identifies 14 environmental issues and covers two aspects: environmental quality of the building, and environmental management of the entire project. The two aspects have been translated into linked reference frameworks, with performance criteria in the first and management requirements in the second. This "two-in-one" concept is HUE's most original aspect.

Figure 2
HQE: minimum environmental profile



The HQE Association, whose members range from French ministries and other government agencies to engineering firms, architects and construction material manufacturers, was founded in 1996. The following year it defined the 14 environmental issues. These fall into four main areas, the first two having to do with the exterior environment and the second two with the interior (Table 1).

Three levels of performance were set: "basic," corresponding to current regulations or normal practice; "good"; and "very good".

Certification will be granted upon achievement of a "minimum environmental profile" (Figure 2) comprising a "very good" rating for at least three issues, "good" for at least four and "basic" for no more than seven.

For the "good" and "very good" rankings, a "principle of equivalence" is allowed. That is, the applicant can suggest an alternative assessment approach to that described in the HQE reference framework in the case of any of the 14 issues.

Assessment is voluntary, but certification will require verification by an independent body. Later a further stage is to be developed, covering operation and maintenance of the building.

The main users of the HQE approach thus far, both before its formalization in 2002 and during the test period, have been public authorities. The method is geared particularly to use by building owners and managers.

Strengths

The technical part of the system is structured along a set of 14 issues that is now well known by French professionals, having been disseminated through conferences, training programmes, written publications, etc. for five years.

Weaknesses

The system still meets opposition and criticism among some designers. These critics think the HQE approach should remain a "free movement" used voluntarily. They fear standardization of the approach will lead to building design driven by certification requirements.

CASBEE (Japan)

The Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) was introduced in 2002. It involves environmental assessment of buildings using categories labelled "Q, Building Environmental Quality and Performance" and "L, Building Environmental Loadings". The categories are defined in accordance with hypothetical boundaries around a building site. Once assessment results are found for each category, Building Environmental Efficiency (BEE) can be determined: BEE = Q/L.

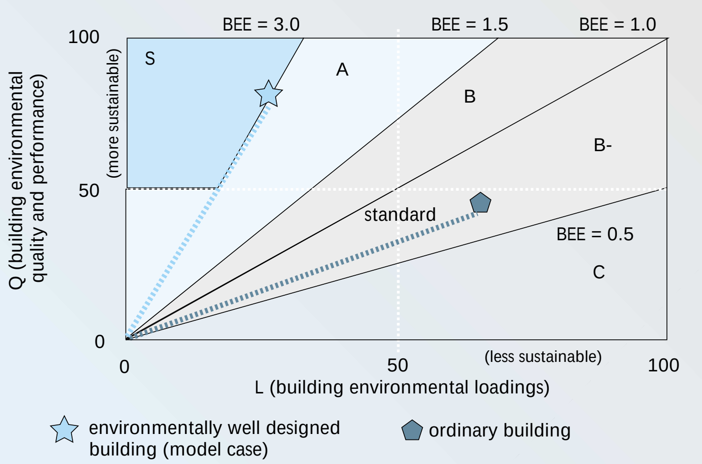
A graphical expression based on BEE suggests how it can be applied to a building's environmental labelling. If Q is plotted on the vertical axis and L on the horizontal axis, the BEE values can be displayed as the gradients of lines connecting the assessment results and the origin (0,0) (Figure 3). The assessment results can thus be presented in the following classes, in order of increasing BEE values: C (less sustainable), B-, B+, A and S (more sustainable).

CASBEE was developed by representatives of government, academia and industry as a joint project. It covers four assessment aspects: energy consumption, resource productivity, local environments, and indoor environments.

It will comprise four assessment tools and a design process. Among the tools, only the "design for environment" (DfE) tool has been completed thus far. The others concern pre-design assessment, eco-labelling, and sustainable operations and renovation. Software and user manuals are being developed for application of the DfE tool and applied in various types of buildings. The results of these assessments are under review.

CASBEE is expected to be used initially by designers and building engineers, with later

Figure 3
Graphical expression of environmental labelling based on BEE



use extending to the entire construction sector and to clients.

Conclusions

Principles of sustainability need to be integrated into the maintenance and management of buildings, addressing environmental targets of global, national, regional and local relevance for the short, medium and long term.

A clear link between environmental issues and the impact caused by a building must be established and communicated. The need is for environmental assessment methods that respond to environmental issues and define sustainable levels in the existing language and parameters of the sector.

Although the issues raised in the methods overlap, each country launching a method develops indicators for its own market. The development of environmental assessment tools has been most successful in countries where government, industry, developers, architects and life-cycle specialists develop a common language and indicators.

There is a trend to address environmental issues in relation to decision making steps. Most tools have started from completed design assessments. The latest developments demonstrate that other relevant stages are now also being addressed, such as early design and building management and the operation of existing buildings.

Many of the current assessment methods apply credit systems and weighting methods that are unique to the method and result in unique units. There is a risk that communication about such units, or about a certain rating, will become a target in itself, rather than the relevant environmental issues.

The concept of assessment leading to certification seems successful, and consistent with the working methods of building managers. Some architects and designers, however, reportedly object that this process does not always challenge designers.

Most tools are based on the application of good practice approaches. This limits the assessment to known solutions. The trend towards performance-based assessment may help overcome this drawback, and challenge both designers and building managers to invent innovative solutions.

Table 1
HQE-defined environmental issues

Eco-construction	Comfort
1. Harmonious relationship between buildings and their immediate environment	8. Hygrothermic comfort
2. Integrated choices of construction processes and materials	9. Acoustic comfort
3. Low-nuisance construction sites	10. Visual comfort
Eco-management	11. Olfactory comfort
4. Energy management	**Health**
5. Water management	12. Sanitary conditions of indoor spaces
6. Waste management	13. Air sanitary quality
7. Repair and maintenance management	14. Water sanitary quality

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Deconstruction: the start of a sustainable materials strategy for the built environment

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Summary

Disposal of buildings in most industrial and emerging industrial countries is wasteful and problematic. Waste from building demolition (partial demolition for renovation, or total demolition for building removal) represents 30-50% of total waste in most of these countries. Deconstruction is an alternative to demolition. It calls for buildings to be dismantled or disassembled, and for the components to be reused or recycled. A number of economic and social benefits can be realized by shifting towards better materials recovery practices in the construction sector. Deconstruction preserves the invested embodied energy of materials, thus reducing inputs of new embodied energy during materials reprocessing or remanufacturing. The concept of design for disassembly (DfD) of buildings emerged in the early 1990s. Closing construction materials loops will require including both product design and deconstruction in a process that might be called "design for deconstruction and disassembly" (DfDD).

Résumé

Dans la plupart des pays industriels ou émergeants, le démantèlement des bâtiments est une source de gaspillage et de problèmes. Les déchets de démolition (qu'il s'agisse de démolition partielle avant rénovation ou de démolition totale et définitive) représentent 30 à 50 % du volume global des déchets dans la plupart de ces pays. Or, il existe une alternative à la démolition : " la déconstruction ". Elle consiste à démonter les bâtiments et à réutiliser ou recycler leurs différents éléments. L'adoption de meilleures pratiques de valorisation des matériaux dans le secteur du bâtiment présente un certain nombre d'avantages économiques et sociaux. La " déconstruction " préserve le contenu énergétique des matériaux, réduisant ainsi l'apport de nouveau contenu énergétique lors du retraitement ou du reconditionnement des matériaux. Le concept de bâtiments conçus pour leur démontage a été introduit au début des années 1990. Pour pouvoir boucler la boucle des matériaux de construction, il faut intégrer la conception des produits et le démontage au sein d'un processus que l'on pourrait qualifier de " conception pour la déconstruction et le démontage ".

Resumen

La supresión de edificios en la mayoría de los países industriales e industriales emergentes genera desechos y problemas. Los desechos de la demolición de edificios (demolición parcial para renovación o demolición total para remover el edificio) representan 30 a 50% del total de desechos en la mayoría de estos países. La deconstrucción es una alternativa a la demolición. Para ello, los edificios deben ser desmantelados o desarmados y sus componentes reutilizados o reciclados. Se pueden obtener beneficios sociales y económicos adoptando mejores prácticas de recuperación de materiales en el sector de la construcción. La deconstrucción preserva la energía invertida e incorporada en los materiales reduciendo así la introducción de nueva energía incorporada al procesar o manufacturar nuevamente los materiales. El concepto de "diseñar edificios para su desmantelamiento" surgió a principio de los años 1990. Para lograr cerrar el ciclo de los materiales de construcción será necesario incluir el diseño y la deconstrucción del producto en un proceso que podría llamarse "diseñar para la deconstrucción y el desmantelamiento".

The materials behaviour of the construction sector of the economy must be characterized as poor during all phases of the building materials cycle – from extraction to construction to final disposal of buildings at the end of their useful lives. Changing this situation will be quite difficult. However, the first steps in the process are under way in at least a dozen countries worldwide. Buildings are being disassembled rather than demolished, and building components and materials are being recovered or recycled for reuse in existing or new buildings. In the Netherlands, for example, at least a dozen different precast reinforced concrete systems have been developed to allow buildings to be disassembled, moved and reconfigured. One of these is the MXB-5 dry-assembly system, in which columns with steel plates at each end are connected to floor elements that have anchor bushings embedded in the concrete. The elements can be connected simply by tightening the connecting bolts. Serious efforts are also being made in several other countries to design buildings for eventual deconstruction.

Initial economic analysis indicates that resale of valuable recovered materials can far offset the additional labour costs associated with building dismantling. New industries to disassemble buildings, process used building components, and resell components and recovered materials can result from implementing deconstruction practices on a large scale. These outcomes make deconstruction an approach well worth considering for countries in which there is significant waste from demolition activities, as well as from natural hazards such has earthquakes and hurricanes.

Deconstruction has several advantages over conventional demolition. It also faces several challenges. Some of the advantages are:

- an increased rate of diversion of demolition waste from landfills;
- potential reuse of building components;
- increased ease of materials recycling;
- enhanced environmental protection, both locally and globally.

Deconstruction preserves the invested embodied energy of materials, thus reducing the input of new embodied energy in reprocessing or remanufacturing materials. A significant reduction of landfill space can also be a consequence. In the United States, where construction and demolition waste represents about one-third of the total volume of materials entering landfills, a diversion rate of 80% is being experienced for deconstructed buildings. In the Netherlands increasingly scarce land is being preserved for other uses. In some countries, businesses have developed the technology and techniques to turn former demolition debris into useful aggregate. The clean, sized aggregate in the photo on the next page is processed concrete, masonry and ceramic waste that can be used as a partial aggregate replacement in new concrete or for road sub-base.

The challenges faced by deconstruction are significant, but they can readily be overcome if changes in design and policy occur. They include:

- Existing buildings have not been designed for dismantling;
- Building components have not been designed for disassembly;
- Tools for deconstructing existing buildings often do not exist;
- Disposal costs for demolition waste are frequently low;
- Dismantling buildings requires additional time;
- Re-certification of used components is not often possible;
- Building codes often do not address the reuse of building components;
- Economic and environmental benefits are not

well established.

These challenges generally fit into the categories of design or policy.[1]

Changing attitudes to building reuse and disposal can increase the materials recycling rate from 10-20% of materials removed from the built environment each year to the 60-70% range and cut demolition waste in half. This can be accomplished by:

- ◆ designing building products that can be disassembled and recycled;
- ◆ designing buildings that can be deconstructed at times of major renovation and at the end of their useful lives;
- ◆ providing incentives for building reuse instead of new building.

The economic and environmental benefits of success would be profound, providing a potentially cheap source of high-quality materials for building products and enormously reducing materials extraction. In an environmental sense, success in closing materials loops even partially in the construction industry would have benefits an order of magnitude or more greater than in any other industry due to the sheer scale of its materials consumption.

Dutch MXB-5 system: reinforced concrete buildings can be dismantled and reassembled at new locations, as dictated by government policy and economics

Clean, sized aggregate processed from building demolition waste at the POWSUS plant in the Netherlands

Materials flows in the construction sector

Flows of construction materials dominate materials flows in most economies. In the United States, as of November 2002, the annualized value of construction was US$ 843 billion. In an economy of about US$ 10 trillion, the construction industry represents about 8.4% of GDP. When the building product sector is included, an additional estimated US$ 400 billion of GDP can be attributed to construction – a total of US$ 1.2 trillion, or about 12% of GDP.

The materials and waste impacts of these activities are even more significant. The construction sector uses more materials than any other industrial sector by far. Of the 1.9 billion metric tonnes that ended up as domestic stocks in 1996, about 1.6 billion metric tonnes became part of buildings or infrastructure. Extrapolating back up the supply chain, and noting the factor of 8 relationship between total materials extracted and the resulting domestic stocks, it is probable that 13-14 billion metric tonnes of total domestic output was associated with building construction.[2]

With respect to domestic stocks, that is, materials that end up in the economy in some fashion, buildings differ significantly from durable goods. Buildings are unique industrial products compared to other human artifacts due to their individuality, longevity and method of assembly. Unfortunately, it is these same characteristics of buildings that make their materials cycle performance very poor. Buildings and their components, building products, have not historically been designed to be recycled or reused, much less disassembled. The building, which represents the "macro" scale of the problem, is assembled from building products using mechanical, thermal and chemical fastening methods and techniques. The products, representing the "meso" scale of the materials cycle, are assembled without regard to their fate. Most are composite materials that are challenging if not impossible to disassemble. The materials used in building products (the "micro" level) are selected for their performance but also for least cost.

Table 1
Factors that increase the difficulty of closing materials loops for the built environment

1.	Buildings are custom designed and custom built by a wide array of actors
2.	A single "manufacturer" is not associated with the end product
3.	Aggregate (for use in sub-base and concrete), brick clay block, fill and other products derived from rock and earth are commonly used in building projects
4.	The connections of building components are defined by building codes to meet specific objectives (wind load, seismic requirements) and not for ease of disassembly
5.	Building products have not historically been designed for disassembly and recycling
6.	Buildings can have a very long lifetime that exceeds that of other industrial products; consequently, materials have a long residence time
7.	Building systems are updated or replaced at intervals during the building's lifetime: finishes at five-year intervals; lighting at 10-year intervals; heating, ventilation and air-conditioning (HVAC) systems at 20-year intervals

Building materials are overwhelmingly the largest constituent of net additions to the domestic stock in most countries. In the US durable goods such as cars, electronic goods and household appliances account for, at most, 1-2 metric tonnes per capita of materials added to stock each year, while the built environment contributes perhaps as much as 20 metric tonnes of stock per capita each year. The decision whether to shift to deconstruction is a very important national consideration, given the huge quantities of materials involved.

The residence time or useful lifetime of construction materials is long compared with the relatively short residence time of other durable goods. Buildings undergo major renovations on 20-year cycles (about the outer limit of the lifetime of automobiles). They can have useful lives of several hundred years. Even in mature industrial economies with significant road, rail and housing infrastructure, there is not yet any sign of significant reductions in the quantities of new construction materials required each year. Annual enlargements of stock of materials have remained remarkably constant over the past 25 years, rising broadly in line with population growth. These small increases are due to growing demand for transport infrastructure, and to the demand for new housing associated with changing demographic structures and affluence. For example, the number of households is increasing faster than population, as more people live alone or in smaller family groupings. Increasing affluence has encouraged a taste for very large, low-density residences. If this trend continues, many millions of tonnes of minerals will continue to be extracted from the land for the foreseeable future. The most damaging aspects of this trend will be the ongoing loss of productive land, degradation of scenic beauty, fragmentation and disturbance of habitats, and increased pressure on biodiversity.

A variety of economic, technological and cultural factors affect the flow of construction materials. When tracked over time, net additions to stock closely follow economic cycles. Recessions, bull markets, levels of public investment and major construction programmes affect construction materials flows. National building standards and traditions also appear to influence flows to stock significantly, although it is difficult to interpret the data. The large mass of materials flowing into construction in some European countries probably reflects a preference for masonry and stone in construction, rather than the lighter wood and steel techniques favoured in some other countries.

The construction industry also differs from other industrial sectors in that the end products – buildings and infrastructure – are not factory produced with great precision but are generally one-off products where precision is less of a concern, designed by widely varying teams of architects and engineers and assembled at the site using significant quantities of labour from a wide array of subcontractors and craftspeople. The end products are generally not subject to extensive quality checks and testing, nor are they generally identified with their producers, unlike, say, automobiles and refrigerators. In the German automobile industry, application of extended producer responsibility (EPR) is resulting in near closed-loop behaviour; buildings, by contrast, are far less likely to have their components returned to their original producers for take-back at the end of their life cycle. Arguably, EPR could be applied to components that are routinely replaced during the building life cycle and can readily be decoupled from the building structure (chillers, plumbing fixtures, elevators). However, the bulk of a building's mass is not easily disassembled. At present little thought is given in the design process to the fate of building materials at the end of a structure's useful life.[3]

Demolition of Hume Hall, University of Florida, demonstrates a lack of capacity for recovering potentially valuable brick due to inadequate foresight in design and planning

Most industrial products have an associated lifetime that is a function of their design, the materials comprising them and the character of their service life. The design life of buildings in the developed world is typically specified at around 50 to 100 years. However, the service lives of buildings are unpredictable because the major component parts of the built environment wear out at different rates, complicating replacement and repair schedules. These variable decay rates have been referred to as "shearing layers of change", which create a constant temporal tension in buildings. Faster-cycling components, such as elements comprising the space plan, are in conflict with "slower materials" such as the structure and the site. For example, electrical and electronic components in a typical office building wear out or become obsolete at a fairly high rate compared with the long-lived building structure. At some critical threshold the motivation to maintain the overall building ebbs and the building rapidly falls into disuse and disrepair simply due to the degradation of the faster, more technology dependent components.[4]

A new paradigm: design for deconstruction and disassembly

It is clear that the current state of construction is wasteful and will be difficult to change. Of all the issues facing the rapidly growing high-performance green building movement, the choice of building materials and products is by far the most difficult. Criteria for materials and products for the built environment should be similar to those for industrial products in general. Many materials used in buildings are the same as those used in other industries, most notably metals. But buildings have a distinct character compared to other industrial products. The major differences that make the closing of materials loops in this segment of the economy particularly difficult are indicated in Table 1. The vision of a closed loop system for the construction industry is, of course, one that is integrated with other industries to the maximum extent possible. Many materials, such as metals, can flow back and forth for numerous uses. Others, such as aggregates and gypsum drywall, are unique to construction and their reuse or recycling would stay within construction. Closing materials loops for the built environment will be significantly more difficult due to the factors that make its materials cycles differ significantly from those of other industries.

The notion of design for disassembly (DfD) of buildings emerged in the early 1990s. DfD must be considered at the design stage to be effective. It has also been noted that DfD can reduce long-term waste generation. Experiments concerned with DfD conducted at Robert Gordon University in Aberdeen, Scotland, included a wide range of issues that were considered to facilitate a greatly improved materials cycle: handling, materials identification, simplicity of construction techniques, exposure or mechanical connections, independence of structure and partitioning, and making short life-cycle components most accessible.

Research indicates that DfD must consider three levels of the entire materials system in buildings to produce sound product design and construction strategies: systems level, product level, and materials level. Several DfD examples do exist that test various ideas that are part of this concept. A multi-storey residential housing project in Osaka, Japan, uses a reinforced concrete frame to support independently constructed dwellings that can be replaced without removing the supporting

Progress in deconstruction of one of several 100-year-old houses in Portland, Oregon, by a non-profit company

South African workers making stabilized earth block using local soils (two Agrément Certificates have been issued for different types of earth block produced during pilot projects in South Africa)

frame on 15-year cycles. Task Group 39 (Deconstruction) of the Conseil International du Bâtiment has been examining the issues of DfD and deconstruction through collaboration of countries throughout the world. Closing construction materials loops will necessitate the inclusion of product design and deconstruction together in a process that might be labelled design for deconstruction and disassembly, or DfDD.

Philip Crowther of Queensland Technical University suggests principles for building DfD. This comprehensive list covers a wide range of thinking about materials selection, product design, and deconstruction (Table 2).[5]

Crowther's work serves as an excellent starting point for considering how to begin the discussion of a comprehensive approach to developing a seamless framework for closing construction materials loops. These principles, although thorough, perhaps generate as many questions as they answer. An example is Principle 4, calling for avoiding composite materials. In the context of materials, "composite" can have many meanings, such as mixed materials (concrete, steel) or homogeneous layered materials (PVC pipe, laminated wood products). Composites may, in fact, be very acceptable under certain conditions where recycling the composite mixture is feasible or where the ability to readily disassemble the layers has been designed into the product. The question is how to develop a systematic approach to deciding the acceptability of composites as building materials within the context of attempting to increase reuse and recycling.

The deconstruction or disassembly of buildings, and materials reuse, is one area of endeavour in which there has been a great upswing in activity and interest in the past few years. For example, in the US several crews employed on a full-time basis by a non-profit corporation in Portland, Oregon, are engaged in taking apart houses and recovering materials for resale in the do-it-yourself market. In a number of countries similar efforts are under way to include building systems that can be disassembled and reused.

Table 2
Principles of design for disassembly (DfD) as applied to buildings

1.	Use recycled and recyclable materials
2.	Minimize the number of types of materials
3.	Avoid toxic and hazardous materials
4.	Avoid composite materials and make inseparable products from the same material
5.	Avoid secondary finishes to materials
6.	Provide standard and permanent identification of material types
7.	Minimize the number of different types of components
8.	Use mechanical rather than chemical connections
9.	Use an open building system with interchangeable parts
10.	Use modular design
11.	Use assembly technologies compatible with standard building practice
12.	Separate the structure from the cladding
13.	Provide access to all building components
14.	Design components sized to suit handling at all stages
15.	Provide for handling components during assembly and disassembly
16.	Provide adequate tolerance to allow for disassembly
17.	Minimize numbers of fasteners and connectors
18.	Minimize types of connectors
19.	Design joints and connectors to withstand repeated assembly and disassembly
20.	Allow for parallel disassembly
21.	Provide permanent identification for each component
22.	Use a standard structural grid
23.	Use prefabricated sub-assemblies
24.	Use lightweight materials and components
25.	Identify point of disassembly permanently
26.	Provide spare parts and storage for them
27.	Retain information on the building and its assembly process

Developing country issues

Perhaps surprisingly, developing countries are in a sense better equipped to deal with deconstruction and materials reuse compared with developed countries. These countries tend to use local materials and vernacular architecture, often creating buildings with the inherent capacity to be dismantled and the components reused. For example, use of timber from sustainably managed forests is another effective use of materials in that these forests are protected to the maximum extent possible and the wood can easily be extracted and reused when the building's useful life has been reached. *Agenda 21 for Construction in Developing Countries* provides a detailed framework for considering deconstruction and other sustainable measures for the construction industries of developing countries.[6] It points out that use of traditional measures and building can be a starting point for research into sustainable technologies. Consequently, the experience of developing countries can serve as valuable input for developed countries as they seek to redesign buildings to accommodate deconstruction and materials reuse. Developed countries will have to consider the techniques and materials being used in developing countries in order to successfully close materials loops in their construction industries.

Lack of modern construction materials in developing countries forces innovation. One major success story in developing country sustainable construction efforts is the development of modern versions of earth block. The employment of earth block, made from local soils and sometimes with a relatively small amount of cement as a binder, has been a highly successful enterprise in several developing countries. The New Gourna mosque in Luxor, Egypt, was built with sun dried earth blocks. Several pilot projects in South Africa have used earth block made with simple machinery that can use human or motor power to produce high-quality, stabilized earth block. Both traditional houses and modern houses are being built from earth blocks in South Africa. This "technology" is attracting significant attention from developed country sustainable building movements, which are attempting to find more natural, ecologically friendly building materials and methods.

Policy implications

National and local government policy can contribute to the implementation of deconstruction as standard practice. Economic instruments are by far the easiest means of fostering the improved materials practice of disassembling buildings to recover materials. In particular, government can assist this shift by increasing waste disposal costs and providing tax advantages for recovered materials. The cost of land disposal of demolition waste is very cheap and is, in effect, subsidized by governments. Through significant increases in disposal costs, the rates of recycling and reuse of demolition waste also increase. For example, in Portland, when disposal costs were raised to over US$ 50 per metric tonne, the recycling rate of demolition waste jumped from about 20% to more than 50%.

Portland is also the location of a non-profit company, DeConstruction Services, which provides building owners with evidence of the value of materials recovered during their deconstruction activities. The materials are donated to another non-profit company that uses the materials to aid local charities in home construction; the owner, with this evidence in hand, can deduct a percentage of the value of the materials from income taxes. This provides a tremendous incentive for building owners to specify deconstruction rather than demolition for disposing of buildings.

The key non-economic instrument local governments can offer is to legislate that time must be provided for deconstruction when an organization applies for a demolition permit. Because time is the crucial factor needed for deconstruction, mandating that time be provided in the overall schedule for a new project involving demolition is of enormous assistance to businesses engaged in deconstruction and materials recovery.

Conclusions

Deconstruction offers an alternative to demolition that is not only an improved environmental choice but can create new businesses engaged in dismantling buildings, transporting recovered components and materials, remanufacturing or reprocessing components, and reselling used components and materials. Existing buildings, though not designed to be taken apart, are in fact being disassembled to recover materials. The benefits of increasing the recycling rates of materials from buildings from the 20% range to in excess of 70% are enormous, as waste from demolition and renovation activities can comprise up to 50% of national waste streams. Economic and non-economic policy instruments can assist in the shift from demolition to deconstruction by providing financial incentives and aiding in providing the time needed for deconstruction. In the developing world, building deconstruction practices offer a source of high-quality materials to assist in improving the quality of life and also the potential for new businesses that may provide economic opportunity for their citizens.

Notes

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Integration of EMS into national regulatory frameworks for offshore oil and gas production

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Summary

Driven by pressures from the public, market pressures and their own self-interest, companies (e.g. in the offshore oil and gas sector) rely on environmental management systems to effect substantial improvements in environmental performance. Models of these systems have been standardized, including by the International Organization for Standardization (ISO standards) and the European Union (EMAS). To ascertain whether (and how) governments integrate EMS into prescriptive regulations for better environmental performance, profiles of six national environmental regulatory frameworks are compared and analyzed in this article. Successful EMS adoption by governments, within a regulatory framework, can increase the efficiency and effectiveness of regulatory mechanisms.

Resumé

Sous la pression du public et du marché, mais aussi dans leur propre intérêt, les entreprises (par exemple l'industrie pétrolière et gazière offshore) s'appuient sur des systèmes de gestion environnementale pour améliorer de façon substantielle leurs performances. Des modèles de ces systèmes ont été normalisés, notamment par l'Organisation internationale de normalisation (normes ISO) et par l'Union européenne (EMAS). Pour savoir si (et comment) les gouvernements intègrent les systèmes de gestion environnementale dans les réglementations contraignantes visant à améliorer les performances environnementales, l'auteur a analysé et comparé les profils de six cadres réglementaires nationaux sur l'environnement. Il semblerait que, bien menée, l'adoption de systèmes de gestion environnementale au sein d'un cadre réglementaire augmente l'efficacité et les performances des mécanismes réglementaires.

Resumen

Motivadas por presiones del público, presiones del mercado y su interés propio, las empresas (en el sector del petróleo offshore y del gas, por ejemplo) utilizan sistemas de gestión medioambiental para mejorar significativamente su actuación medioambiental. Algunos modelos de estos sistemas han sido normalizados por la Organización Internacional de Normalización (normas ISO) y por la Unión Europea (EMAS). Para determinar en qué medida (y cómo) los gobiernos integran sistemas de gestión medioambiental en las reglamentaciones para una mejor actuación medioambiental, se comparan y analizan los perfiles de seis marcos nacionales de reglamentaciones ambientales. El éxito en la adopción de sistemas de gestión medioambienal por parte de los gobiernos, dentro de un marco reglamentario, puede aumentar la eficiencia y eficacia de los mecanismos reglamentarios.

Offshore production is a significant source of crude oil and gas supply in several oil-producing countries. However, offshore oil and gas exploration and production has serious environmental impacts. These include pollution from oil spills, accidents and fires (some of which have been intensely publicized) and the continuing impacts of operational discharges, atmospheric emissions and negative social pressures in coastal areas.

The challenge posed by sustainable development is to meet world energy demands with minimum impacts on the environment. National laws remain the means by which countries meet their international environmental obligations and regulate the conduct of companies and individuals within their borders. National regulation has traditionally been prescriptive, based on "command and control" legislation that specifies permits, prohibitions, emission standards, monitoring mechanisms, and, occasionally, environmental impact assessment (EIA). Such systems often prescribe fixed minimum standards applicable to existing problems. Thus they are not readily adaptable to newer environmental approaches such as the precautionary principle.

Prescriptive legislation does not usually aim to achieve compliance and environmental performance beyond required minimal standards. The significance of environmental management systems and standards is that they encourage environmental performance beyond minimal standards. This proactive response has been prompted by the modern drivers of environmental compliance: public disclosure, market pressure and self-interest. Regulatory controls independent of EMS will not create sufficient incentive for the introduction of cleaner technologies or environmentally friendly innovations.

Standardized environmental management systems such as the International Organization for Standardization's ISO 14000 series and the EU's Eco-management and Audit System (EMAS) make use of registration and certification procedures to ensure uniform reliable and verifiable application. Within this framework, other management tools employed to improve performance include environmental assessment (involving strategic and risk assessment), environmental auditing and public corporate environmental reporting. These systems and tools have resulted in a number of actions and procedures that could be effectively "captured" by regulation to achieve improved environmental performance.

This article presents a brief overview of regulatory mechanisms. It examines the mode of – and the extent of integration between – such mechanisms within the given examples of national regulatory frameworks for environmental regulation of offshore oil and gas production. It concludes with some thoughts on the necessity for an integrated approach.

Environmental issues relevant to regulation of the offshore oil and gas industry are listed in Table 1.

Types of regulatory mechanisms

Traditional command and control (C&C)

Several governments, when confronted with the task of providing a national environmental framework that will reflect their international commitments and effectively improve environmental performance in the industrial sector, have chosen prescriptive legislation (traditional command and control) involving some of the following instruments:

- permits;
- prohibitions;
- emission standards;
- monitoring;
- environmental impact assessment (EIA).

Prescriptive environmental regulation is generally found in a variety of national laws. These include general petroleum or planning laws and regulations developed to deal with specific environmental issues (Table 2).

Environmental management systems and tools

EMS types

Environmental management systems can be defined as "the organizational structure, responsibilities, practices, procedures, processes and resources for implementing and maintaining environmental management." EMS also takes account of those aspects of management that plan, develop, achieve, implement, control and improve the enterprise's environmental policy, objectives and targets.

The use of environmental management systems is still in its early stages and will continue to develop. The following types have emerged:

- company in-house EMS systems;
- association framework EMS;
- standardized models of EMS.

Five standards in the *International Organization for Standardization (ISO) 14000 series* were published in 1996, creating a framework for environmental management systems. In this series companies are registered only with respect to ISO 14001. The other standards are guidance documents. Companies that intend to be certified under this series must meet the specific requirements of ISO 14001, which requires:

- formation of an environmental policy;
- planning of environmental objectives and targets;
- implementation and operation;
- checking and corrective action involving internal auditing;
- management review.

The ISO 14001 standards focus on structural requirements in any organization desiring to implement, maintain and improve an environmental management system. Such an organization must provide a framework for setting and reviewing environmental objectives and targets, and this should be properly documented and communicated to all employees and made available to the public.

The *Eco-management and Audit Scheme (EMAS)* was set up by the European Union for establishment and implementation by companies within the Community engaged in industrial activities. To participate in EMAS, these companies must:

- adopt a company environmental policy;
- conduct an environmental review of the site;
- introduce an environmental programme on the basis of review;
- carry out environmental audits;
- set objectives for continuous improvement of their environmental performance.

The company is to prepare an environmental statement designed for the public, and verified by an accredited environmental verifier.

Table 1
Environmental issues relevant to the offshore oil and gas industry

Environmental issues	Potential impact areas
direct environmental impact of activities.	• atmospheric • aquatic • biosphere • potential accidents
waste management	• aqueous discharges • solid waste • mud & cuttings • atmospheric emission/noise/light
decommissioning and rehabilitation	• removal • restoration
health & safety	• impact of chemical use & exposure • fire risk • impact on workforce
human & social impact	• impact on local population • change in water use patterns • effect on socio-economic systems

Source: Details collated from several sources, including Z. Gao (ed.), *Environmental Regulation of Oil and Gas*, 1998, and UNEP.

EMS tools

EMS provides a comprehensive set of tools for use within the environmental management system. These tools are structured instruments for improving decision making or information management (or for effecting changes in the behaviour of others), with the overall aim of improving the industry's environmental performance. All the key actors (e.g. companies, governments) can use environmental management tools to monitor and improve environmental performance. These tools include:

- public corporate environmental reporting;
- voluntary codes;
- environmental assessment (EA) (risk and strategic);
- environmental auditing;
- voluntary/negotiated agreements.

Economic and tax instruments

These instruments are based on a different approach to influencing pollution activities, aiming for an indirect effect by internalizing externalities where financial tools (e.g. a carbon tax) can reflect the cost of such externalities. An acceptable classification has been set out by the Organisation for Economic Co-operation and Development (OECD). It proposes five groups:

- charges;
- subsidies;
- deposit-refund systems;
- market creation;
- financial enforcement incentives.

Table 2
Types of environmental legislation

Environmental protection
Health and safety
Environmental impact assessment
Clean air and water
Water catchment protection
Integrated pollution prevention and control
Discharge and management of waste
Waste disposal
Prohibited chemicals
Transport of dangerous substances
Marine pollution
Marine navigation and safety
Fishery protection
Protected areas
Protection of cultural heritage

Comparative analysis

A comparative analysis of instruments applicable in six countries is presented in Tables 3-6. Each country has significant offshore oil and gas production. These tables allow an overview of the use of similar mechanisms in different countries.

The following is a summary of national profiles. The complete text of these profiles is available on the Offshore Oil and Gas Environment Forum (OEF) Website (www.oilandgasforum.net/ management/regula/nationalprofiles.htm). Profiles were compiled with the assistance of the appropriate national authorities.

Abu Dhabi

Abu Dhabi, in the United Arab Emirates, has a legislative framework with a de facto regulator, ADNOC (the national oil company). ADNOC shares this responsibility with the UAE Federal Environmental Agency. While ADNOC has no operations of its own, it controls operating companies and reports to the Abu Dhabi Supreme Petroleum Council. The fundamental environmental legislation is the Federal Environmental Law, which requires permitting of the offshore oil and gas industry, environmental impact assessment of development projects, and development of environmental guidelines by the UAE Federal Environmental Agency (FEA). Management instruments exist but are not required by regulations.

Australia

The approach used in Australia is similar to that in the UK (below). Australia has a federal structure. State and territorial legislation is applicable to offshore activities within three nautical miles of the shore. Two basic pieces of environmental legislation are applicable to offshore activity: the Petroleum (Submerged Lands) Act (PSLA) and the Environmental Protection and Biodiversity Conservation Act (EPBC). The EPBC is triggered only where the proposed activity would affect matters of environmental significance. This includes impacts on World Heritage sites, Ramsar wetlands, nationally threatened species and ecological communities, migratory species, commonwealth marine areas and nuclear activity. The 1999 Regulations for management under the PSLA require an extensive environmental plan before petroleum activity is undertaken; the EPBC (where triggered) requires extensive environmental assessment, public environmental reports, public enquiry and approval of the Minister of Environment and Heritage. In Australia there is also active cooperation among regulators,

Table 3
Command and control mechanisms[1]

Issues	Abu Dhabi	Australia	Malaysia	Norway	United Kingdom	United States
Climate change				Pollution Control Act, not yet permits regarding specific emissions	Petroleum Production Act Prevention of Oil Pollution Act (used to regulate flaring/ venting)	Clean Air Act
Ozone protection	Vienna Convention for the Protection of the Ozone Layer. Montreal Protocol on Substances that Deplete the Ozone Layer	Ozone Protection Act	Vienna Convention for the Protection of the Ozone Layer Montreal Protocol on Substances that Deplete the Ozone Layer	Pollution Control Act, permits	Montreal Protocol 1987 EU regulations on ozone depleting substances 92/3952 EEC	
Water pollution	Regional Convention for the Marine Environment Marine Pollution Convention (Special Areas)	Petroleum (Submerged Lands) Act	EEZ Act Merchant Shipping (Oil Pollution) Act	Pollution Control Act, Regulations on Oil Discharges from Drill Cuttings, permits	MARPOL incorporated in the Merchant Shipping Acts. Prevention of Oil Pollution Act-oil spill plans required. Oil Pollution Preparedness Response Regulation	Federal Water Pollution Act (Clean Water Act) Oil Pollution Act
Waste disposal	Basel Convention London (dumping) Convention	Protection of Sea (Pollution from Ships) Act PSL Act	Environment Quality Act Basel Convention	Pollution Control Act, Petroleum Act, permits	Radioactive Substances Act Waste Management Licensing Regulations Special Waste Regulations Food and Environment Protection Act	Resource Conservation and Recovery Act
Impacts on ocean ecology		EPBC Act Fisheries Management Act PSL Act		Petroleum Act	Draft Offshore Petroleum Activities (Conservation) of Habitats Regulations 2001	Endangered Species Act Marine Mammal Protection Act
Coastal zone management				Pollution Control Act, Petroleum Act, permits	Coastal Protection Act	Coastal Zone Management Act
Decommissioning		Environmental Protection (Sea Dumping) Act PSL Act		Plan required in the Petroleum Act, permits	Operators submit abandonment programmes or DTI approval.	Permit required.
Chemical safety contamination		Industrial Chemicals (Notification/ Assessment) Act PSL Act	Petroleum (Safety Measures) Act	Permits for the use and discharge of chemicals	Draft Offshore Chemicals regulations 2001	OHS
Overall environment	Federal Law No. 24 for 1999 for the Protection and Development of the Environment (Federal Environment Law)	Exploration Permit Pipeline and Production License PSL Act EBPC Act Aboriginal and Torres Strait Islander Heritage Protection Act Australian Heritage Commission Act Historic Shipwrecks Act Navigation Act	EQA 1974 and its regulations EEZ Act 1984	Regulations relating to: • management systems, • risk analysis, • emergency preparedness. Permits are issued for the exploration and production phases. Punitive measures in place for non-compliance	IPPC- The Offshore Combustion Installations (Prevention and Control of Pollution) Regulations 2001 Offshore Petroleum Production and Pipe-line (Assessment of Environmental Effects) Regulations 1999 Submarine Pipelines Act Licences required for exploration and production stages. Discharge permits required.	EIS Ports/Waterways Safety Act National Historic Preservation Act Permits required at various stages of the exploration and production cycle. Punitive measures in use.

1. Command and control: permits, approvals, licenses, release standards

Table 4
EMS and tools[1]

Issues	Abu Dhabi	Australia	Malaysia	Norway	United Kingdom	United States
Climate change		APPEA Greenhouse Challenge reporting				
Ozone protection						
Water pollution						Environmental reporting for oil spills SEMP
Waste disposal						SEMP
Impacts on ocean ecology	ADNOC Cleaner Seas Campaign					
Coastal zone management				*		
Decommissioning				*		
Chemical safety contamination				OLF collects data on chemicals	Offshore chemicals notification scheme	SEMP
Overall environment	ADNOC HSEMS based on E & P Forum HSEMS model and ISO 9001 and 14001 compliant	DISR Environmental Plan EPBC environment assessment and approvals APPEA Code of Practice - ISO 14000	DOE E IA, EMP Format, Proposed audit scheme	Environmental reporting required by govt. & Industry on air emissions and sea discharges. *Industry monitors operators in these issues. * Reporting and monitoring is required. The authorities audit the industry on a regular basis	EIA for new projects. Environmental statement for new projects. Voluntary EMAS by the EU.	Govt. performance reporting programmes Industry reporting via SEMP Industry also gathers data throughout US for environmental performance reporting

1. Management instruments: reporting, auditing, monitoring

the Department of Industry, Science and Resources (DISR), Environment Australia (EA) and the industry. The industry association, the Australian Petroleum Production and Exploration Association (APPEA), has a Voluntary Greenhouse Challenge Agreement with the federal government to report annually on emissions. EA and APPEA have also signed a Memorandum of Understanding that aims to increase cooperation on conservation of the marine environment.

Malaysia

In Malaysia there is an emphasis on legislation, with the Malaysian Department of Environment as main regulator. It shares this task with other government agencies and the national oil company, PETRONAS. The Petroleum Mining Act 1966 designates PETRONAS as the petroleum authority within the offshore areas. The two major pieces of environmental legislation applicable to Malaysian offshore activities are the Environmental Quality Act and that concerning Malaysia's Exclusive Economic Zone (EEZ), which require environmental impact assessment, environmental quality monitoring and reporting.

Norway

Norway has a legislative framework in place, complemented by voluntary measures such as formal alliances between government and industry and a consultative forum. The coordinating regulator, the Norwegian Petroleum Directorate (NPD), issues licenses for offshore activity. Licenses must contain information on planned activities, technical solutions, and implementation and use of management systems. The Norwegian Pollution Control Authority (SFT) is a specific regulatory authority for matters concerning oil pollution response and oil and chemical discharges to the sea. The industry association (OLF) produces the annual Norwegian Oil Industry Association Environmental Report and encourages voluntary use of ISO 14000 and EMAS. Norway taxes CO2 emissions from petroleum activity on the continental shelf.

United Kingdom

A fundamentally prescriptive environmental framework applies to the offshore industry in the UK. The Department of Trade and Industry (DTI) is the lead regulator. Other agencies (e.g. the Environment Agency, the Scottish Environmental Protection Agency) regulate offshore activities within a three-mile coastal limit. DTI requires companies operating in offshore areas to obtain licenses at the exploration and production stages. These licenses include conditions relating to environmental protection. DTI also carries out regular monitoring and surveillance flights. The UK regulatory picture features an active relationship with the industry association, the United Kingdom Offshore Operators Association (UKOOA). DTI works with UKOOA to obtain data from industry; in areas where legislation does not exist, agreements are negotiated. The EU regulation on voluntary use of EMAS is applicable.

United States

The US implements offshore policy on natural energy through the Minerals Management Service (MMS). In this task it shares some responsibility with the Environmental Protection Agency (EPA), which regulates air and water quality. In the US the emphasis is on legislation and programmes to regulate industry and improve environmental performance. The Safety and Environmental Management Programme (SEMP) is a process for coordinating outer continental shelf (OCS) oil and gas operations, focusing on worker safety and pollution control. The National Environmental Policy Act (NEPA) requires environmental assessment and environmental impact statements. The MMS requires permits for offshore operators. While there is a strong industry association, the American Petroleum Institute (API), with several voluntary standards and an annual environmental performance report, the US's profile does not indicate serious cooperative efforts between industry association and government. Environmental auditing is carried out by operating companies without government participation, except on request. The MMS is required to give environmental reports to Congress every

Table 5
Negotiated agreements for joint actions

Issues	Abu Dhabi	Australia	Malaysia	Norway	United Kingdom	United States
Climate change					Voluntary Code on Atmospheric Emissions-UKOOA Guidelines for Reducing Atmospheric Emissions from Oil/Gas Facilities-UKOOA	
Ozone protection						
Water pollution					Code on Synthetic Drilling Fluids-UKOOA	
Waste disposal						
Impacts on ocean ecology					Code on Seismic Activity-UKOOA	
Coastal zone management					Guidelines on Exploration Operations in Nearshore/ Sensitive Areas-UKOOA	
Decommissioning						
Chemical safety contamination						
Overall environment		APPEA Code of Practice EA + APPEA Agreement	No negotiated agreements	OLF has Environment Programme and includes • research, coordination, analytical reports MILJØSOK • consultative forum	Atlantic Frontier Environment Network Joint Nature Conservation Committee UKOOA have produced • Statement of Guidelines for Offshore Environment • Guidelines on Internal Audit and Training • Guidelines on EMS	SEMP

Table 6
Economic instruments[1]

Issues	Abu Dhabi	Australia	Malaysia	Norway	United Kingdom	United States
Climate change				CO_2 Tax		
Ozone protection						
Water pollution						Oil Pollution Act-penalties for liabilities
Waste disposal						
Impacts on ocean ecology						
Coastal zone management						
Decommissioning						
Chemical safety contamination						
Overall environment	Economic incentives not used	Economic incentives not used Punitive measures in place	Economic incentives not used		No economic instruments in place	Economic incentives not used

1. Economic instruments: taxes, fees, liabilities, incentives

three years on the cumulative environmental effects of these activities. MMS works closely with outer continental shelf (OCS) operators to voluntarily incorporate the Safety and Environmental Management Program (SEMP) into their operations for worker safety and pollution control. The regulatory framework does not acknowledge use of environmental management systems or ISO 14001.

Conclusion

These profiles indicate a traditional command and control framework, with slight references to EMS. The Norwegian profile reflects the best advances made towards integration. The recommended integrated approach refers to the effective "capture" of standardized EMS certification processes and tools in a legislative framework. Such a system, when in place, creates an incentive for companies that adopt and practise association or standardized environmental management systems. In other words, there is a benefit in place for achieving higher standards than what would otherwise be required by law. This would imply an integrated framework relying on the EMS certification processes. External verification by accredited third-party agencies is strongly recommended for the sake of transparency. The enabling prescriptive legislation within such framework would focus on defaulters and accreditation procedures for such third- party verifying bodies.

Efficient use of the certification and verification procedures of standardized systems such ISO 14000 and as EMAS would also lead to practical use of human and financial resources. It would create added incentive for improvements, as being seen as "certified and green" becomes important.

The need for such incentives in the offshore oil and gas industry is highlighted by the call for investment in several developing countries. These countries are tempted to lower environmental standards as a bargaining chip. However, with such integration compliance becomes a competitive advantage.

Within developed countries, where governments seek to encourage investment in marginal and unexplored fields, these lower costs can be obtained using an integrated approach.

The application of international EMS and tools would internationalize these standards in each country, so that companies could no longer complain of oppressive environmental standards. Conversely, these standards themselves will provide for compliance with legislation applicable within such countries and can be adapted to suit any individual country requirements. This flexibility would make it possible to include disclosure and verification requirements, as well as lists of accredited third-party verifiers. Countries with such a programme of integration could strike a balance between EMS regulated activity and legislation.

Given the complex nature of the environment and the multifaceted impact of offshore oil and gas exploration and production activities, the actions indicated in the profiles are inadequate. There is room for additional improvements, which could be achieved through the integrated approach and with greater cooperation from industry. ◆

Energy, development and climate change: considerations in Asia and Latin America

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Summary

The main findings of two high-level regional workshops organized in 2002 – by the International Petroleum Industry Environmental Conservation Association (IPIECA) in Kuala Lumpur, Malaysia, and by the Regional Association of Oil and Natural Gas Companies in Latin America and the Caribbean (ARPEL), IPIECA and UNEP in San Jose, Costa Rica – are presented in this article. The purpose of these workshops was to increase the understanding of regional development and climate change issues, and to identify opportunities for effective near- and long-term action, particularly through the Clean Development Mechanism (CDM). Economic, methodological and institutional barriers to private sector investment in CDM projects still exist. Uncertainties about rules surrounding the CDM have progressed from hypothetical concerns to more practical ones related to institutional capacity to review and approve project applications in a timely and cost-effective manner.

Resumé

L'article présente les principales conclusions de deux ateliers régionaux pour responsables de haut niveau organisés en 2002 à Kuala Lumpur (Malaisie) par l'IPIECA (Association internationale de l'industrie pétrolière pour la sauvegarde de l'environnement) et à San José (Costa Rica) par l'ARPEL (Association régionale des compagnies pétrolières d'Amérique latine et des Caraïbes), l'IPIECA et le PNUE. Le propos de ces ateliers était de permettre une meilleure compréhension des problèmes de développement régional et de changement climatique et de trouver des voies d'action efficaces à court et long termes, notamment à travers le mécanisme de développement propre. Il existe encore des barrières économiques, méthodologiques et institutionnelles aux investissements du secteur privé dans les projets de développement propre. Les incertitudes liées aux règles qui régissent ce mécanisme ont évolué : d'abord hypothétiques, elles sont devenues plus concrètes et concernent la capacité institutionnelle de vérifier et d'approuver en temps utile et de façon économiquement avantageuse les propositions de projets.

Resumen

El artículo presenta los principales resultados de dos talleres regionales de alto nivel organizados en 2002 por la Asociación Internacional de Conservación Medioambiental de la Industria del Petróleo (IPIECA) en Kuala Lumpur, Malasia y por la Asociación Regional de Empresas de Petróleo y Gas Natural en Latinoamérica y el Caribe (ARPEL), IPIECA y PNUMA en San José, Costa Rica. El propósito de los talleres era lograr una mejor comprensión de cuestiones relativas al desarrollo regional y al cambio climático e identificar las oportunidades para tomar medidas eficaces a próximo y largo plazo, en particular mediante el Mecanismo de Desarrollo Limpio (MDL). Todavía existen obstáculos económicos, metodológicos e institucionales para que el sector privado invierta en proyectos de MDL. Las incertidumbres sobre la reglas relacionadas con el MDL han evolucionado de preocupaciones hipotéticas a preocupaciones más prácticas relacionadas con la capacidad de las instituciones de revisar y aprobar aplicaciones de proyectos de manera oportuna y eficaz en materia de costos.

IPIECA, the International Petroleum Industry Environmental Conservation Association, was founded in 1974 following the establishment of UNEP in 1972. IPIECA is the petroleum industry's principal channel of communication with the UN. It is accredited with the UN Economic and Social Council (ECOSOC) as an ECOSOC Category II non-governmental organization, which provides IPIECA with formal observer status in UN programmes. The IPIECA membership consists of both petroleum companies and associations at the national, regional and international levels. It is the single global association representing the petroleum industry on key environmental and social issues, including:

- global climate change;
- biodiversity;
- social responsibility;
- fuel quality and vehicle emissions;
- human health; and
- oil spill preparedness and response.

IPIECA promotes scientifically sound, cost-effective, practical, socially and economically acceptable solutions to these global issues. In pursuing this mission, IPIECA works in cooperation with industry, government, regulatory bodies, international agencies, academia and NGOs.

Climate change is a global environmental concern with potentially significant consequences for society, with respect to the possible future impacts of climate change and to the socio-economic consequences of policies proposed to respond to it. Formed in 1988, the IPIECA Climate Change Working Group (CCWG) monitors, analyzes and informs its membership about key developments concerning this issue, especially those taking place at the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC). The CCWG encourages the development of policy options that strike a balance between the projected consequences of potential climate change and the estimated costs of response options to mitigate or adapt to climate change. The IPIECA CCWG sponsors dialogues and workshops addressing key aspects of the ongoing negotiations. It provides a technical publication series as a form of constructive input to the process.

IPIECA held two high-level regional workshops in 2002 addressing the issues of energy, development and climate change. Each of these events brought together about 100 experts from academia, business, governments, international institutions (e.g. the UN Development Programme, UNEP and the World Bank), emissions trading groups, and oil and gas industry climate change experts. The first workshop at Kuala Lumpur, Malaysia, aimed to increase understanding of Asian development and climate change issues, and to identify opportunities for effective near and long-term actions, particularly through the Clean Development Mechanism (CDM).

The second event, organized jointly with the Regional Association of Oil and Natural Gas Companies in Latin America and the Caribbean (ARPEL) and UNEP, was held at San Jose, Costa Rica. This workshop aimed to address more practical issues associated with the opportunities for and barriers to developing CDM projects in Latin America and the Caribbean. This article summarizes the main findings of the two workshops. The key messages of the two workshops are presented in Table 1.

Background to the workshops

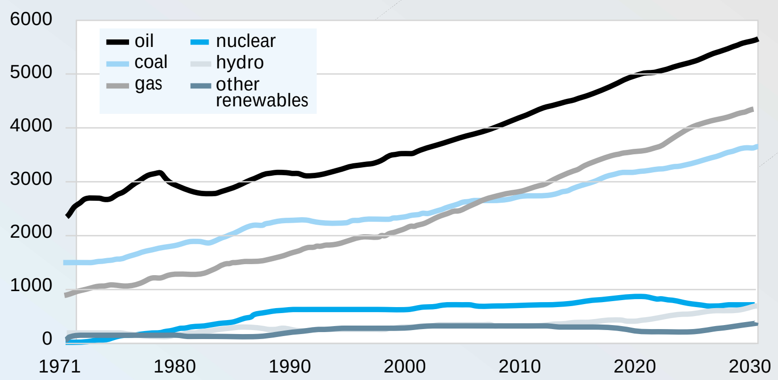
A driving goal for developing nations is to achieve economic development similar to OECD countries. This will lead to increasing energy consumption and emissions for some time to come. The UNFCCC has noted that emissions originating in developing countries will grow to meet their social and development needs.[1] The World Summit on Sustainable Development (WSSD) made clear the importance of affordable energy, and its role in poverty alleviation. The Johannesburg Plan of Implementation includes the urgent goal of creating access to modern energy services for 1.6 billion people who currently do not have access to modern energy services.[2]

The Organsation for Economic Co-operation and Development (OECD)/ International Energy Agency (IEA) *World Energy Outlook* projects that over the next 30 years global primary energy demand will grow by 1.7% per year, from 9200 to 15,300 million tonnes of oil equivalent (Mtoe), and that this demand will be met primarily by increased consumption of oil, natural gas and coal. Energy from renewable resources is also expected to grow, but will remain a small percentage of the total energy mix (Figure 1).[3] It is also projected that many of the 1.4 billion people living at or below the poverty line will remain without access to electricity, which is an essential requirement for social and economic development.[3]

Table 1
Key messages

- ◆ The alleviation of poverty and the provision of clean water, health services, sanitation facilities, and primary education are the key near-term priorities in the developing world. Actions to mitigate the long-term risk of climate change must be considered within this context.
- ◆ Energy demand and consumption over the next 30 years in Asia and Latin America is forecast to grow rapidly, with this demand being met primarily by increased consumption of fossil fuels, thus posing a fundamental challenge to meet developmental goals whilst at the same time addressing increased greenhouse gas (GHG) emissions.
- ◆ There is considerable emissions reduction potential for CDM projects in Asia and Latin America, but the current focus on small-scale energy efficiency improvement and renewable energy schemes will not realize this potential.
- ◆ Individual nations still vary in their capacity to review CDM projects. Governments can play key roles in CDM project development by ensuring that all national sustainable development criteria are met, and by government-facilitated agreements between multilateral funding agencies and the private sector.
- ◆ Added to concerns about the uncertainties and impractical requirements around additionality and baselines for the CDM are practical concerns about institutional capacity to process project applications in a timely and cost-effective manner. It remains unclear what sort of CDM projects will be awarded CERs.
- ◆ Investment in CDM projects will be dwarfed by the overall investment in energy, especially in Asia, through to the end of the Kyoto Protocol's first commitment period in 2012.
- ◆ Over the next decade the petroleum industry will make investments leading to development, the transfer of technology, and emission reductions or avoidance that will go far beyond what may receive credits under the Kyoto Protocol.
- ◆ Emission reduction targets and timetables specified by the Kyoto Protocol are for the first commitment period from 2008 to 2012. It remains unclear what international framework may evolve after that and what future obligations might be undertaken by developing countries.
- ◆ The development and deployment of technologies that result in significant emission reductions need to be a key part of any future strategy, but it remains unclear what kind of international framework will ensure that this occurs.

Figure 1
Trends in world primary energy demand, 1971-2030



Source: based on data from *World Energy Outlook 2002* (OECD/IEA)

Energy and development in Asia, Latin America and the Caribbean

Reflecting a rapid growth in demand for energy, the IEA has noted that fossil fuel consumption in developing countries is expected to surpass that of developed ones by 2030 (Figure2). Developing regions will account for 65% of the 45 million barrel/day increase in global oil demand between 2000 and 2030, with Asian countries constituting the largest share. In East Asia, excluding China, growth in CO_2 emissions is projected to increase from 1.1 billion tonnes in 2000 to 2.8 billion tonnes in 2030, whilst in Latin America emissions are projected to rise from 0.9 to 2.1 billion tonnes over the same period.[3]

In Kuala Lumpur it was noted that over 500 million people in Southern Asia live on less than US$1 per day, and that the provision of affordable and reliable energy to communities currently without access to electricity will be a key requirement for regional development.[4] At both workshops it was emphasized that climate change mitigation is not a near-term priority, with the provision of primary education, medical facilities, regular employment, clean water supplies and proper sanitation having priority on national development agendas. Regional representatives also emphasized the need for climate change strategies to be considered within the context of these national sustainable development priorities.

> "Ultimately, congruence between mitigation projects and sustainable development goals is not only a sovereign right but also a national priority"
>
> Franz Tattenbach, UNDECOR, Costa Rica[5]

CDM objectives, project type and potential

The CDM offers one pathway to encourage technology transfer, promote sustainable development and reduce GHG emissions. The three aims of the CDM, as specified in Article 12 of the Kyoto Protocol, are:

- ◆ to promote sustainable development in non-Annex 1 countries;
- ◆ to help achieve the ultimate objective of the Convention to stabilize atmospheric concentrations of GHGs;
- ◆ to assist Annex 1 parties in cost-effectively meeting their obligations under the Protocol.[6]

For non-Annex 1 developing countries, the CDM promises to create a reduced-emission infrastructure, support national sustainable development objectives, promote technology transfer, build local capacity and attract foreign investment. The need for CDM projects to meet developing country sustainable development objectives and encourage technology transfer was emphasized, with the generation of Certified Emission Reduction credits (CERs) to meet Annex 1 party objectives being of secondary importance. The project cycle for a CDM project is shown in Figure 3.

Although the potential for CDM in Asia is considerable, project and institutional activity is more developed in Latin America. The emission reduction potential in both Asia and Latin America is on the order of hundreds of millions of tonnes of CO_2, with large-scale CDM projects (e.g. fuel switching from coal to oil and gas, CO_2 capture and geologic sequestration, LNG for replacing coal-fired power generation, and reduction of flaring and venting) accounting for the bulk of this potential. Current activity, however, is on small-scale emission reduction projects, particularly renewable energy (hydro, solar, wind, biomass and geothermal) and energy efficiency projects. A diverse range of candidate CDM projects were presented in Kuala Lumpur and Costa Rica (Table 2).

In comparing the candidate CDM projects presented and host countries' project expectations, the following points were noted:[7]

- ◆ Most CDM projects are being developed in the larger Asian and Latin American economies;
- ◆ Project developers in Latin America emphasized the environmental and emission reductions bene-

Table 2
Examples of candidate CDM projects presented at workshops

Asia [4]
◆ wind power, small-scale hydro and biomass in India
◆ geothermal and gas venting elimination in Indonesia
◆anaerobic digestion and municipal waste management in the Philippines
◆ bio-diesel and oil palm in Malaysia
◆ biomass energy and anaerobic digestion in Thailand
◆ clean coal technologies in China
Latin America and the Caribbean [5]
◆ reforestation and geological sequestration in Argentina
◆ gas flaring abatement and co-generation in Mexico
◆ utilization of associated gas previously flared, fugitive gas emissions and energy efficiency in Brazil
◆ waste treatment, landfill gas and cement production in Costa Rica
◆ river run-off hydro power project in Chile
◆ wind farm project in Colombia
◆ carbon sinks and fugitive gas emissions in Venezuela

fits of CDM, whilst in Asia the emphasis was on the need for sustainable development and poverty eradication;
◆ Forestry and natural resource based projects were being developed by host countries in Latin America and the Caribbean region, but did not rank highly with national authorities in Asia;
◆ More CDM projects are currently being developed in Latin America and the Caribbean region than in Asia.

CDM institutional considerations

It was noted that national and international processes to review and approve CDM projects have developed rapidly over the last months, but that much work remains to be done. The establishment of Designated National Authorities (DNAs), responsible for reviewing, recommending and submitting projects for approval to the CDM Executive Board, advanced the furthest in Latin America with eleven of the fourteen developing country DNAs registered with the UNFCCC secretariat (June 2003).[8] However, in both Latin America and Asia many countries have yet to establish DNAs, and many have an urgent need to develop local capacity and expertise. The two workshops clearly illustrated a diversity of national approaches to establishing DNAs, in part reflecting different national priorities and circumstances.

Project potential and business perspectives

The fledgling CDM market is dominated by projects in Latin America. Future CDM investment in both regions is expected to come from a variety of sources, including Annex B governments, multinational corporations, international financial institutions (e.g. World Bank Prototype Carbon Fund, PCF), development agencies (e.g. UNDP), and local and national companies. Further clarity on procedural and project related CDM issues will be required before significant levels of investment, trading in CERs or technology transfer occur. It was also noted that the anticipated level of investment through CDM would be several orders of magnitude lower than that in the energy sector over the same period.[7]

It was emphasized that if the CDM is to attract private sector investment, clarity is needed on a wide variety of issues (Table 3). It was also recognized that projects must be based on sound economics, as the generation of CERs will in most cases affect economic returns only at the margins. The need to "learn by doing", building knowledge and confidence through actually developing projects, was emphasized by many participants.

Oil and gas industry considerations

Large-scale CDM projects have substantial emission reduction and technology transfer potential but are currently receiving little attention at the international negotiating level, resulting in a lack of focus at national levels. The oil and gas industry is particularly well suited to deploy large-scale projects with significant emissions reduction potential (Table 4). However, it was also noted that these types of projects currently face technical challenges (e.g. defining baselines and determining additionality) and that their political acceptability remains uncertain (e.g. eligibility, approval process).

Table 3
CDM issues requiring further clarification[7]

◆ clear guidance on project eligibility criteria
◆ acceptable methodologies for calculating emission baselines
◆ criteria for determining whether projects meet additionality criteria
◆ time frame for processing and approving projects
◆ project information requirements
◆ level of transaction costs
◆ future price of Certified Emission Reductions (CERs)

Table 4
Examples of large-scale CDM oil and gas projects[7]

◆ energy efficiency improvements
◆ utilization of associated gas previously flared
◆ large-scale fuel switching projects (e.g. from coal to oil and natural gas)
◆ capture of vented methane
◆ carbon dioxide capture and storage

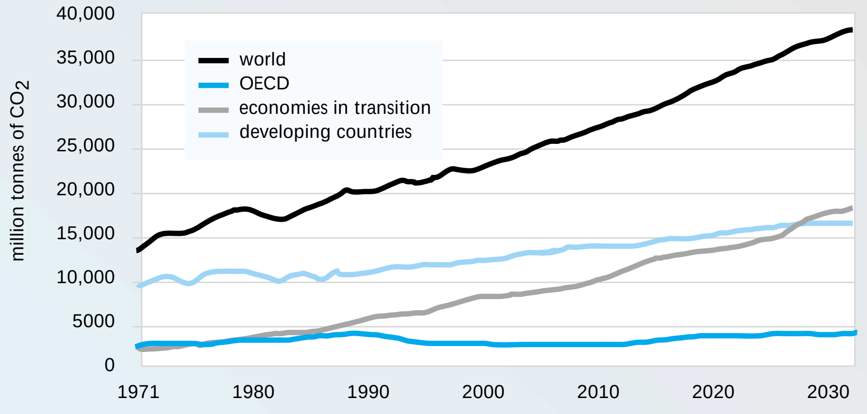
Looking forward...

Many participants reflected that short-term international mechanisms, such as the CDM, cannot alone address the long-term challenges and risks associated with global climate change. Measures included under the Kyoto Protocol are only likely to have a marginal affect on climate change. Given that the emission reduction targets and timetables set by the Protocol only apply to developed countries for the first commitment period up to 2012,[6] it remains unclear what kind of international framework may evolve after that to address the deep cuts in global emissions that may be needed to meet the UNFCCC stabilization goal. Some attendees emphasized that the development and deployment of efficient commercial technologies that lead to significant emission reductions need to be a key part of future climate change strategies, but it remains unclear what kind of international framework would ensure that this occurs.

Conclusions

The alleviation of poverty and the provision of clean water, health services, sanitation facilities and primary education are key priorities in the developing world. With 1.6 billion people worldwide lacking access to modern energy services, the provision of affordable energy is a key requirement for economic and social development in Asia and Latin America. Actions to mitigate and adapt to the long-term risk of climate change must be considered within this context. Reflecting increasing development in Asia and Latin America, energy demand is forecast to grow rapidly over the period of 2000 to 2030. Projec-

Figure 2
Energy-related CO_2 emissions by region, 1971-2030



Source: based on data from *World Energy Outlook 2002* (OECD/IEA) tions show that this demand will be met primarily by increased consumption of fossil fuels. This poses a challenge to meet developmental goals whilst at the same time addressing increased GHG emissions.

The global deployment of economically viable existing technologies that result in low GHG emissions and the development of improved technologies are key elements to address this challenge. The CDM provides one pathway to encourage technology transfer, promote sustainable development and reduce GHG emissions. There is considerable emissions reduction potential for CDM projects in Asia and Latin America. The current focus, however, is on small-scale energy efficiency improvement and renewable energy schemes. In order to realize the potential of the CDM, large-scale projects will be required. This is particularly true for oil and gas projects. Capacity for governments and companies in both regions to address the development of CDM projects has increased, but individual nations still vary in their capacity to review CDM projects. Several countries in both Asia and Latin America have established, or are planning the establishment of, Designated National Authorities (DNAs) needed to approve projects in the host countries.

There currently remain economic, methodological and institutional barriers to private sector investment in CDM projects. Uncertainties about the rules surrounding the CDM have progressed from the more hypothetical concerns about additionality and baselines, to more practical concerns about institutional capacity to review and approve project applications in a timely and cost-effective manner. While concerns and detailed issues about additionality and baselines remain, the development of more projects and the series of international negotiations and clarification of proposed rules and processes have led to an improved understanding of the CDM since the first of our workshops cited here. No CDM projects, however, have yet (as of June 2003) been approved by the international Executive Board of the CDM, and it is unclear what sort of CDM projects will be awarded CERs.

Future CDM investment in both regions is expected to come from a variety of sources, including Annex B governments, multinational corporations, international financial institutions (e.g. the World Bank PCF), development agencies (e.g. UNDP), and local and national companies. Investment in CDM projects will, however, be dwarfed by the overall investment in energy, especially in Asia, through to the end of the Kyoto Protocol's first commitment period in 2012. Over the next decade, the petroleum industry will make investments leading to development and the transfer of technology, and emission reductions or avoidance that will go far beyond that which may receive credits under the Kyoto Protocol.

Emission reduction targets and timetables specified by the Kyoto Protocol are for the first commitment period from 2008 to 2012. It remains unclear what international framework may evolve after that and what future obligations might be undertaken by developing countries. It is clear that the development and deployment of technologies that result in significant emission reductions need to be a key part of any future strategy, but the framework within which this can occur remains uncertain.

> "Developing countries and the poorest people who live in them are the most vulnerable to climate change. Yet it is also they who are most in need of sustainable energy services to meet their livelihoods, growth and development needs."
>
> Arun Kashyap, UNDP

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Notes

1. UNFCCC (1994) Convention on Climate Change.
2. WSSD (2002) Johannesburg Plan of Implementation.
3. OECD/IEA (2002) *World Energy Outlook 2002*.
4. IPIECA (2002) *Development and Climate Change: Issues and Approaches in Asia*.
5. ARPEL, IPIECA, UNEP (2003) *A Practical Approach to Identifying Emission Reduction Opportunities: Examples under the Kyoto Mechanisms in Latin America and the Caribbean*.
6. UNFCCC (1997) *The Kyoto Protocol*.
7. IPIECA (2003) *Energy, Development and Climate Change: Considerations in Asia and Latin America*.
8. UNFCCC (2003) CDM website (http://cdm.unfccc.int/)

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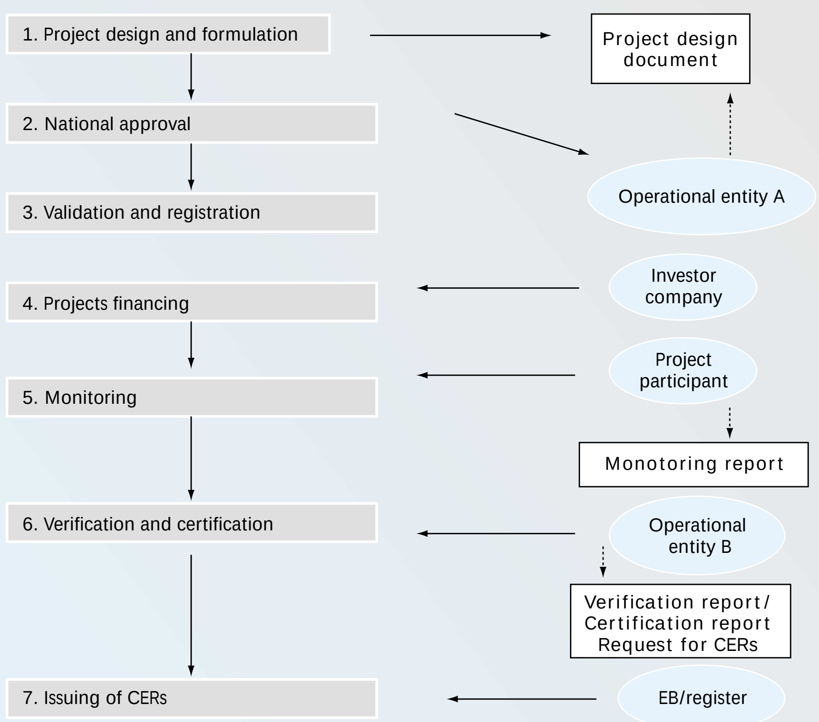
Figure 3
CDM project cycle



Source: UNEP