Improved quality of life through passive solar design

Recent studies have shown that 1 100 people die daily in Sub-Saharan Africa from indoor air pollution. By (re)designing houses with energy efficiency in mind, the amount of energy needed to keep a house comfortable can be reduced dramatically; thus lessening the health and economic burden on these households.

By Wim Klunne

The application of simple, passive solar design principles can dramatically improve a homeowner's quality of life. Poor households in particular can benefit significantly from houses designed around passive solar design guidelines. Currently, these households spend large portions of their income on energy services for lighting, cooking and heating. Space heating is mostly done using (indoor) air polluting fuels like coal or wood.

Typically, low cost housing in South Africa is of poor quality, with inferior thermal performance characteristics. Relatively simple interventions such as correct orientation of new houses or providing ceilings in existing houses can bring about significant benefits; not only in the form of reduced expenditure on space heating fuels, but also in terms of improved indoor air quality, as well as a reduction in the emission of hazardous greenhouse gases like CO_2.

Passive solar design intervention can be categorised into no-cost or low-cost, medium-cost, and high-cost interventions. The no-cost or low-cost interventions are pure necessities and will yield very short payback periods. In most cases, they are affordable to the homeowner. Medium- and high-cost interventions might require more of an investment. An appropriate system to monitor reduced indoor air pollution should be devised. Avoiding greenhouse gas emissions might be rewarded through the existing Clean Development Mechanism (CDM) if simple monitoring and validation methods can be developed. To avoid healthcare costs, a system of health credits could be arranged.

Passive solar design

This involves the incorporation of energy flow principles (while considering the region's climatic conditions) into the design, construction and management of a house. The idea is to achieve thermal comfort with minimal conventional energy input. The basic components of passive solar design include ensuring correct orientation of the house, optimising natural sunlight through daylighting, and utilising thermally efficient building materials. Applying these principles is a low- or no-cost intervention, applicable in all climatic regions. However, they need to be considered in the planning and design phases of construction, as the nature of these interventions makes them unsuitable for retrofitting.

Orientation ofthe house

Passive solar design can reduce the energy required to keep a house comfortable. Houses in the Southern Hemisphere should face geographic north ($\pm 15^{o}$) in order to obtain optimal solar benefit. Houses which are north-orientated and have most windows facing north will have the least heat gain in summer and the least heat loss in winter. The orientation of houses involves limited direct costs and should be an integral part of planning and design.

Building materials

Passive thermal design also entails using appropriate building materials, such as those with a high thermal mass, and which are able to store heat during the day and then release it slowly at night. The current trend in low cost housing in South Africa is to use hollow cement blocks for walls and concrete surface beds for flooring, both of which have reasonable thermal capacities. Alternative materials such as earth bricks have much higher thermal capacities but were rejected in earlier projects, as communities perceived them to be inferior materials (Walker 1999). Recently, earth bricks have been more readily accepted, as the houses built using these bricks resemble the appearance of 'normal' houses.

Position and size of glazing

Daylighting refers to optimising natural sunlight through glazed areas in such a way that heat gain is minimised in summer and heat loss minimised in winter (Irurah 2000). Solar radiation transmitted through glass converts to heat when it strikes materials such as concrete floors. It is then re-radiated as heat. According to Holm (Holm 1996), the size of the glazing should be approximately 20% of the total floor area (exact figure depending on the climatic circumstances) and positioned on the northern side of the house for ‘solar collection’ to provide the most favourable thermal efficiency. There should also be minimal window surface facing the south, east and non-west. An effective application of the aforementioned 20% rule can be achieved through the use of trombe walls (thick e.g. masonry walls designed to absorb the sun’s energy during the day, store it, and radiate heat evenly during the night or first overcast day in the winter) on the northern side.

Double-glazing is a thermally efficient principle, which is common practice in areas like Europe where winters are long and cold. This technology is rarely used in South Africa, and as a result, the market is small and prices are high. However, recent market activities have resulted in new double-glazing products entering the market at reasonable prices.

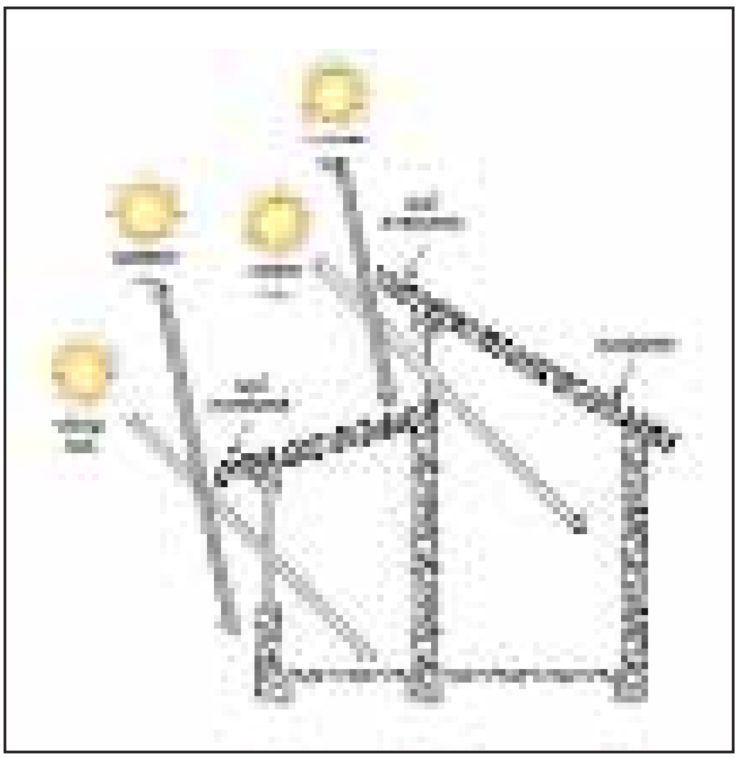
In the inland areas of South Africa, the material used for windows and doorframes is mostly metal, which conducts heat and is therefore responsible for extensive heat loss. Only in the coastal areas (where corrosion is a problem) is wood normally used. Generally, wood is a much better insulator than steel but is seldom used inland due to availability and higher prices.

Roof overhang

The northern orientation of a house should be coupled with a roof overhang on the northern side, designed according to the summer and winter angles of the sun. The size of the roof overhang depends on roof geometry but should be about half a meter in length to shade the northern windows from the sun in summer and allow rays to penetrate in winter, when the sun is lower on the horizon (Garner 1999). Roof overhang should be combined with a strip of grass or vegetation around the house to prevent the surface from heating up too much. This is a low- to medium-cost intervention.

Ceiling

Installing ceilings is critical to achieving a thermally efficient, low-cost house. With their ability to trap air, ceilings ensure a reduction of heat flow in or out of the house. The cost of a traditional ceiling is in excess of R50 per m^2, while new, innovative, low-cost ceilings can be as inexpensive as R25 per m^2. Ceiling insulation is a medium- to high-cost intervention but is an absolute necessity.



Drawing illustrating the principles of passive solar design (source: IIEC – Passive Solar Design Brochure).

Insulation

There are various ways to insulate a wall. Building a cavity wall is seen as the most effective method, but it is also the most expensive and therefore not widely used. Another method, is to plaster walls or use panels; also called construction boards. These panels are either used as an add-on to the walls and thus function as an insulation layer, or they fulfil the wall function themselves. Polystyrene panels applied on the outside of existing walls are very suitable for retrofitting existing houses. Good results have been achieved with this in Europe.

Flooring

Floors are an important feature of thermal efficiency in houses. Flooring material should be of high thermal mass, such as concrete, bricks or clay, in order to trap heat coming in through windows. To achieve maximum results, homeowners should minimise the use of carpets. Single storey residential units can basically use their surface bed (consisting of the floor slab and the soil underneath it) as thermal mass. Multi-storey residential blocks have the disadvantage of having only one level with these characteristics. Increasing thermal mass in the floors between building layers by adding material beyond constructional requirements is often considered too expensive.

Shared walls

Sharing walls saves on the costs of the housing shell, as well as on energy consumption. This can be achieved through building either semi-detached houses or a row of houses. When units share walls, they provide more insulation against heat loss in winter and heat gains in summer. However, some communities do not accept shared walls and argue that: “one must be able to walk around it; otherwise it is not a house”. However, the new policy of the Department of Housing shows a shift away from stand-alone units toward multiple dwelling units.

Urban greening

Improvements to the indoor temperature can be achieved by planting trees around the housing unit, primarily on the north to provide shading. The greenery should be deciduous – providing shade in the summer but allowing solar radiation to penetrate in winter. Planting greenery is also useful for wind protection.

Solar Water Heaters

Although not a passive solar design feature as such (since it concerns an appliance used in the house), the provision of a solar water heater will certainly improve the quality of life of the inhabitants. In cases where other fuels were used to heat the water, energy and expenditure savings are possible with solar water heaters, as well as the reduction of greenhouse gas emissions.

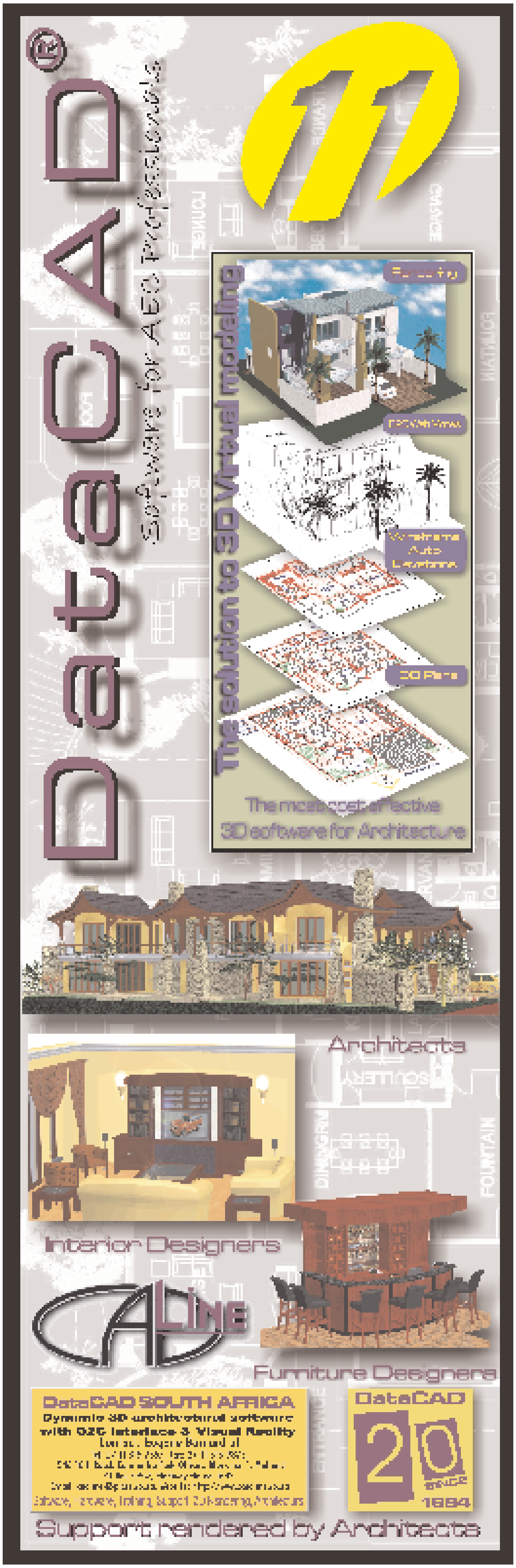
Current energy efficient housing initiatives

Various projects attempting to address energy efficiency in residential housing have been executed in South Africa. Many of them also include other aspects of sustainable living, such as water-or waste-related issues. Unfortunately, all of these projects are stand-alone activities with limited or no interaction. See Table 1 for an overview of such initiatives in South Africa in the low-income housing sector.

Overview of projects targeting energy efficiency in low cost housing in South Africa (based on Klunne, 2002).

name of project	province	rural /urban	density[1]	number of houses	other sustainability aspects[2]	orientation	roof overhang	ceiling	wall insulation	alternative materials	user education	new/ retrofit	energy use monitoring
All Africa Games Village	Gauteng	urban	medium	1799	yes	yes	partially	yes	no	no	no	new	no
Krugersdorp Housing project	Gauteng	urban	low	18000	yes	yes		yes	no	no		new	no
Kutlwanong Eco-housing project	N. Cape	urban	low	200	no	yes	yes	yes	yes	partially	yes	new & retrofit	yes
Ivory Park, mud brick house	Gauteng	urban	low	1	yes	yes	partially	yes	no	yes	yes	new	no
Ivory Park, insulated ceiling	Gauteng	urban	low	30	no	no	no	yes	no	yes	yes	retrofit	no
Mohlakeng, Ext. 2, Randfontein	Gauteng	urban	medium		yes	yes		yes	no	no	yes	new	no
Thermally improved shacks, Mabopane	Gauteng	urban	shacks		no	no	no	no	yes	yes		retrofit	yes
SEED housing Cape Town	W. Cape	urban	low	2300	yes			yes				new	no
Tlholego, Rustenburg	North West	rural	low		yes	yes	yes	no	no	yes	yes	new	no
Alexandra East Bank Housing Development	Gauteng	urban	low	1200	no	yes	no	no	no	no	no	new	no
SOWETO eco home	Gauteng	urban	low	1	yes	yes	yes	yes	yes	no		new	ongoing
Shayamoya - Cato Manor, Durban	KZ Natal	urban	medium	320	yes	yes	no	no	no	no	no	new	no
Missionvale, Port Elizabeth	KZ Natal	urban	medium		no	no	no	no	no	no	no	new	no
Waterloo Development	KZ Natal	urban	low	2	no					yes	yes	new	no
Dutch AIJ (Benoni, Kimberley, Cape Town, Lady Grey)	Gauteng N. Cape W. Cape Free State	urban	low	4 * 4	no	yes	yes	yes	yes	yes	no	new	limited

1) low density refers to stand alone houses, medium density to multiple units combined in one physical structure.
2) 'other sustainability aspects' refers to the application of (grey) water management, solar water heaters, greening of the environment, and the inclusion of recycle-ability of materials.



Surprisingly, very few projects have been evaluated properly in terms of the effect of the interventions on energy usage, except for the Mabopane project and to a limited extent, the Kutlwanong Eco-housing project. For the time being, we have to judge the cost effectiveness of the interventions through computer simulations. After the low-cost principles of passive solar design, ceilings with insulation are the most promising intervention, followed by the insulation of walls with insulation material (like polystyrene) on the outside (Klunne 2002).

The way forward

It should become common practice for all new houses to incorporate at least the principles of passive solar design, supplemented by installation of ceilings. For the middle- and higher-income houses, these features need to be marketed as being essential. The current upward trend in electricity prices certainly favours energy efficiency features in houses.

For the low-income houses, funded through the RDP housing subsidy, a sustainable financing mechanism needs to be developed to cover the additional costs involved. The subsidies provided by the South African Department of Housing are not sufficient. Industry must continue its current commitment towards lowering the prices of energy efficient building materials, and an effective and efficient monitoring and validation method needs to be agreed upon in order to access CDM (Clean Development Mechanism) funds. Avoiding healthcare costs through an improved indoor air climate needs to be capitalised on, either through a health credit scheme or through a direct contribution by the Department of Health.

Existing houses need to be retrofitted wherever possible and made more energy efficient through the installation of ceilings or the use of insulation material. Such actions are currently not common practice. Public awareness campaigns and the development of a support programme in which energy efficient houses qualify for some type of financial incentive or tax rebate, need to be considered.

Wim Klunne is an international renewable energy and climate change expert. He has carried out projects on rural electrification, grid connected renewables and energy efficient housing, mainly in southern Africa. Currently Wim is co-ordinating a renewable energy and energy efficiency project at the African Development Bank. For more information, contact him by email: wim.klunne@microhydropower.net, or visit www.microhydropower.net/klunne.

Literature

Garner, G. (1999). *A model for green housing - The All African Games Village.* Alexandra, South Africa.

Holm, D. (1996). *Primer for energy conscious design.* Pretoria, South Africa, University of Pretoria.

Irurah, D. K. (2000). *Environmentally sound energy efficient low-cost housing for healthier, brighter and wealthier households, municipalities and nation, evaluation of performance and affordability of intervention technologies.* Johannesburg, University of Witwatersrand, University of Pretoria, Energy and Development Research Centre University of Cape Town, PEER Africa.

Klunne, W. E. (2002). *Energy efficient housing in South Africa.* Overview of current state of affairs, possible interventions and the role of carbon emissions related funding to address the situation.

Walker, J. (1999). *A sustainability assessment method for low cost, cement block housing on the Cape flats.* Environmental engineering. Cape Town, South Africa, University of Cape Town.