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AN APPROACH TO SUSTAINABLE, ENERGY EFFICIENT DESIGN FOR LOW - COST HOUSING IN BOTSWANA

by

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ABSTRACT

The study was premised by the apparent lack of sustainability and poor quality of low cost housing of Botswana. The overall aim of the study was to investigate the possibility of integration of sustainability and resource efficiency into housing practice. The research first conducted a desk study into the low cost housing industry of Botswana which was followed by a survey in a representative area of Gaborone, the capital city of Botswana. The survey was in the form of a situational analysis which was conducted through user questionnaires. This was followed by structured interviews that were administered to stakeholders to gain insight into housing and design practice. In order to investigate the performance of different types of existing low cost housing, the following parameters were identified; planning and implementation, housing design, the building envelope and its response to its environment, materials and resources used in low cost housing, their application and consumption pattern.

The study found that sustainable, energy conscious design of housing makes a considerable difference to the building's thermal performance, user comfort, health, appropriate use of resources and the environment. It results in cost savings for services by the occupants, reduces institutional expenditure on programmes and maintenance costs, and reduces the negative impact on the environment by the building sector. Following the research, the study found that for successful integration of sustainability and energy efficiency in low cost housing for Botswana, there must be a balance in the integration of three primary elements; energy efficient housing, culture and regional identity and the environment. Institutional low cost housing was targeted as the first point of intervention for better impact. The study recommended a phased implementation approach.

The output of the study was a framework for the integration of these strategies into new and existing housing for the institutional low cost housing sector.

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ABBREVIATIONS

ASHRAE:

The **American Society of Heating, Refrigerating and Air Conditioning Engineers** is an international technical society for all individuals and organizations interested in heating, ventilation, air-conditioning, and refrigeration.[1] The Society, organized into Regions, Chapters, and Student Branches, allows exchange of HVAC&R knowledge and experiences for the benefit of the field's practitioners and the public. ASHRAE provides many opportunities to participate in the development of new knowledge via, for example, research and its many Technical Committees. These committees meet typically twice per year at the ASHRAE Annual and Winter Meetings.

BHC: Botswana Housing Corporation

Botswana Housing Corporation was established in 1970 by an Act of Parliament CAP 74:03 of 1970. Its role was to provide housing, office and other building needs to government and other local authorities. It then took over all projects that were handled by the then Public Works department (PWD). The present BHC is a parastatal organisation that provides private residential houses; few are remaining for rental and majority for purchase through direct sale and through the Tenant Purchase Scheme. Its functions are mainly influenced by the National Policy on Housing and the National Vision 2016.

BOTEC: Botswana Technology Centre

The Botswana Technology Centre is a Research and Development parastatal organisation established by the Government of Botswana in focusing on the field of science and technology. BOTEC has operating units in Architecture and the Built Environment, Infrastructure Development and Water Engineering, Renewable Energy, Electronics, Communications and Information.

Its main role is to support industrial development through identification of appropriate technological choices in adapting new technologies to meet the changing needs of the country. This includes the provision of advice to government, NGOs, the private sector and

[1] http://www.en.wikipedia.org/wiki/HVAC.jul07.

the public. Its functions include the development of technologies for local use, coordination of technology endeavours within Botswana, assessing technologies for actual and potential impact on development in various sectors, and the development of prototype technologies for industry. BOTEC also monitors and evaluates alternative technologies and assists government and the private sector in identifying opportunities for the application of appropriate technologies. It has played a key role in the development of the Science and Technology Policy for Botswana and its subsequent implementation. BOTEC also carries out consultancies, case studies, testing programmes and technology assessment studies for government and the private sector.

BRET: Botswana Renewable Energy Technology Project

BRET is a project that developed and produced a booklet for use by the SHHA of the Ministry of Local Government and Lands. BRET was a joint pilot project of the Ministry of Minerals Resources and Water Affairs and the United States Agency for International Development (USAID) from 1981 to 1985. It was managed and technically assisted by the Associates in Rural Development, Burlington, Vermont, USA.

DBES: Department of Buildings and Engineering Services

A department of the Ministry of Works and Transport responsible for coordinating the building design, construction and services maintenance of all Government (institutional) staff houses. All 19 Government departments approach DBES with their requests for housing and their budgets. DBES helps them to formulate the brief and decides how the project is handled (whether in-house or outsourced).

DOE Department of Energy

This department is also known as the Energy Affairs Division (EAD). The division was established in 1984 as a unit within the Ministry of Minerals, Energy and Water Affairs (MMEWA). It is responsible for coordinating, directing and formulating national energy policy issues and programmes. In order to execute its mandate EAD is divided into five units namely; Electricity, Coal, New and Renewable Sources of energy, Biomass, Planning & Documentation, and Administration.

DOH: Department of Housing

The Department of Housing was formed in 1994 as a result of the recommendations of the Organisation and Methods Report (O&M) of June 1991 in order to spearhead national housing development programmes with a view to ensuring adequate safe and sanitary shelter for all population groups. The Department is responsible for designing and formulation of housing policies, monitoring and provision of guidance to Local Authorities both urban and rural, private developers and other institutions in the implementation of housing policies.

DTRP: Department of Town & Regional Planning

The Department of Town and Regional Planning was established in 1972. It operates from Gaborone, which is the Headquarters and is responsible for all national physical planning matters. The Department also operates from Francistown, which is the Northern Regional Office. The Regional Office covers in detail the northern part of the country, while the Head Office covers the south. The Department was established as a result of the need to manage the rapid urbanisation and growth of rural and urban centres, and the efficient utilisation of public and private land.

EECBS: Energy Efficiency and Conservation in the Building Sector of Botswana

The EECBS is a project sponsored by DANIDA and the government of Botswana. It is overseen by the Department of Energy, under the Energy Efficiency and Conservation Unit, established in 2000. It aims to reduce the energy consumption in the building sector, and come up with other programmes that will both promote energy conservation and educate the people to be energy conscious.

GDP: Growth Domestic Product

The value of the goods and services produced in a certain period. In Botswana, the figure represents annual growth rate.

GCC Gaborone City Council

Gaborone City Council is the local authority for looking after the city's urban infrastructure and development. It is responsible for regulating building and planning procedures. It is also the mother-body for the SHHA programme.

NDP: National Development Plan of Botswana

National Development Plans (NDP) of Botswana are national developments for Botswana that are planned for long term development planning of programmes for a set period of 6 years. The current plan is the NDP9 which spans from 2003(04) to 2009.

SBAT:

The Sustainable Building Assessment Tool (SBAT) is a design tool that was developed as part of a thesis for the integration of sustainable development in South Africa.

SHHA:

The Self Help Housing Agency (SHHA) programme is a non-conventional shelter strategy which was introduced in 1974 to facilitate the provision of affordable housing to first time low-income urban households. The programme is administered by the City or Town Councils. The government serviced residential plots measuring 375 square metres including roads, drains, drains, potable water, sewerage and electricity. This programme has now been extended to all councils including, city, town, and district councils; so that it becomes part of an overall housing and poverty alleviation strategy nationally.

C h a p t e r 1

THE PROBLEM AND ITS SETTING

1.0 INTRODUCTION

This chapter provides a preamble to the study on sustainable, energy-efficient design for low cost housing in Botswana. The study intends to facilitate the establishment of sustainability and resource efficiency in low cost housing design practice in an aim to improve the building performance of low cost housing. For greater impact, the research targeted institutional urban low cost housing.

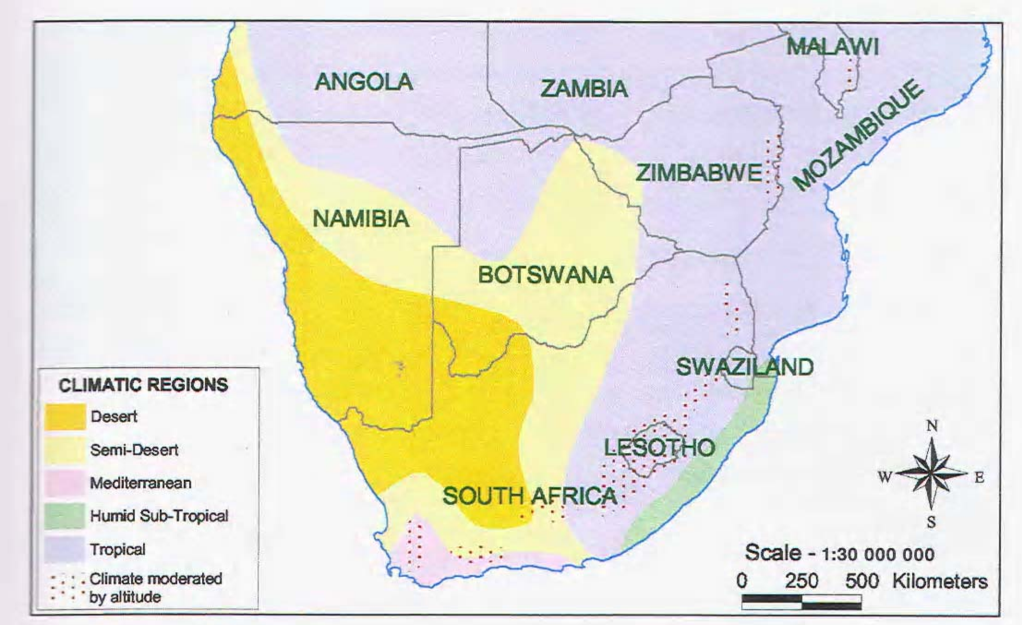
Sustainability and resource efficiency leads to quality, affordable housing and reduces negative impact by the construction sector and housing, on the environment. In the following sections, the study gives a background on Botswana, the research problem and the housing situation that has led to the problem of study.

1.1. COUNTRY BACKGROUND

Botswana is a land-locked sovereign state, situated at the centre of the Southern African Plateau; between latitudes 17deg30' north-west and 28deg south of the equator and longitudes 20 and 29 degrees east of the Greenwich Meridian. She is surrounded by Namibia to the west- north, Zambia and Zimbabwe in the north-east and South Africa in the east and south. The country has a semi- arid climate with hot summers and cold winters and a large diurnal range in temperature over 15 degrees Celsius. Mean annual temperatures vary little over Botswana, from 20 degrees to the south-west to 23 degrees to the north. The rainfall is unreliable, erratic and seasonal. Most rains fall in the summer months between November and March. The effectiveness of the rain is reduced by the high evaporation rates, which are experienced in summer. The mean annual rainfall varies with the south-west receiving less than 250 mm of rain and the north over 650 mm.

Figure 1 below, shows the map of Botswana and its regional context.

FIGURE 1: Map of Southern Africa



Source: Botswana Atlas (2001)

The country is approximately 582,000 square kilometers in size with a population of about 1.7 million people and a low population density with just over 2.6 people per square kilometre. The density is relatively low compared to some countries of similar size such as France and Kenya which have densities of 103.2 and 41.2 people per square kilometre, respectively. However, the population is growing rapidly. Table 1 below, shows population figures over the last decade.

TABLE 1: Botswana Population Figures

1993	1,3 million people
1996	1,5 million people (= 2, 6 people per sq. km)
2001	1,695 million people

Source: Botswana Family Health Survey III (1996) and the Botswana Atlas (2001)

However, the population distribution is uneven with the eastern part of the country highly concentrated due to favourable climate and soil conditions.

The capital city of Botswana, Gaborone, lies on the south-east boundary of Botswana and north-west of South Africa, as depicted in figure 2 below.

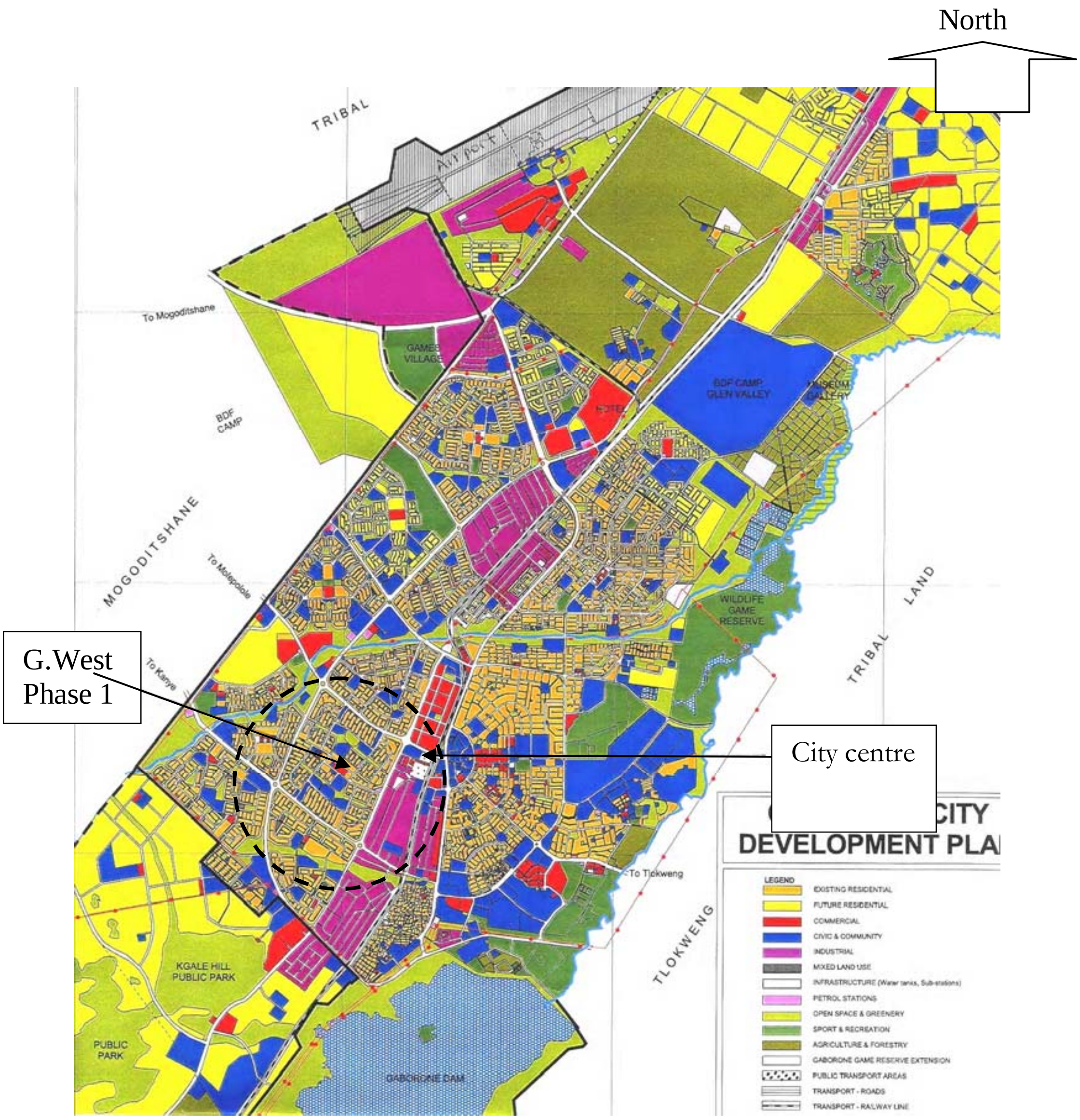
FIGURE 2: Location map of Botswana

Source: www.maps.com/magellangeographix (1997)

According to the last population census of 2001, the population of Gaborone was approximately 224,286 with an annual growth rate of 5.1 % (2001). The population of the city is made up of a diverse community of people of all races.

The city has a grid planning layout that is dominated by the transport layout and characterised on the majority by low housing densities, with single dwelling on a single plot. The layout of Gaborone from the Department of Town and Regional Planning (DTRP) master plan of 2000 is shown by figure 3 overleaf.

FIGURE 3: Gaborone Land Use Plan



Source: Department of Town and Regional Planning, DTRP Master Plan (2000)

The following are the identified challenges facing the city:-

1. The city's planning is mainly characterised by the need to maximise as many basic services such as electricity, water and sewerage to as many plots as possible.
2. Construction developments tend to grow independently of each other, yet they sit in close proximity of each other.
3. Limited choice of quality, affordable low cost housing. The Self Help Housing Agency (SHHA), Botswana Housing Corporation (BHC) and institutional housing

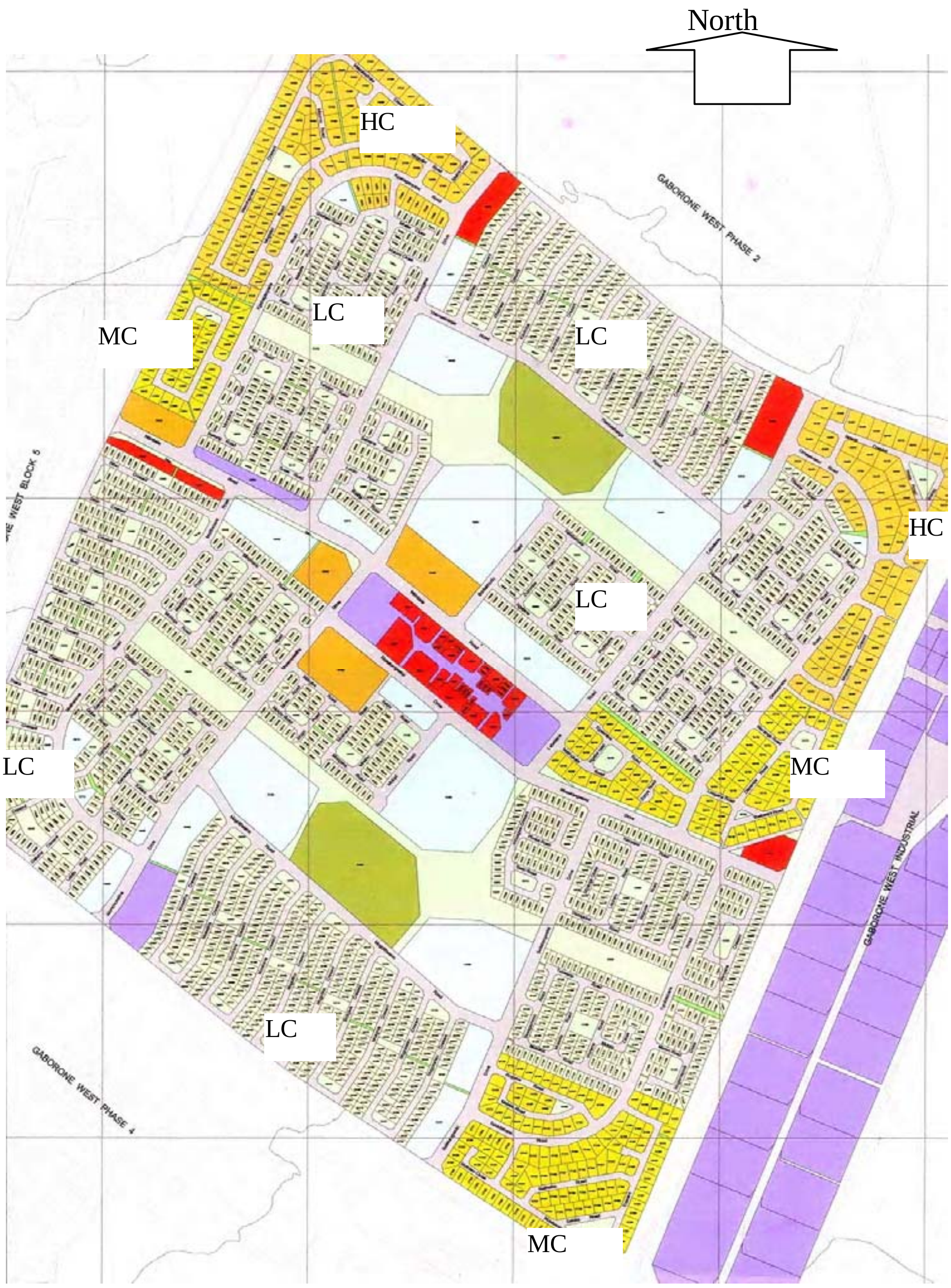
are the main source of housing for the low cost sector; with SHHA catering for the lowest sector offering 1 and 2 roomed incremental "flat roofed" houses. While BHC and institutional low cost houses are on average characterised by 3 to 4 roomed gable roof houses of similar row upon row houses.

A representative residential area of Gaborone was chosen for the purpose of this study. The selected area namely Gaborone West (G. West) Phase1, is a typical urban residential area of Gaborone and Botswana in general. It is one of eighteen residential areas of Gaborone and is only 4 kilometres from the city centre, as indicated in figure 3 above. G.West Phase 1 is bounded by G. West Phase 2 to the east, G. West Block 5 to the west, G.West Phase 4 to the south-west and the G. West Industrial site to the south east.

The area has a population of approximately 15, 000 people. In terms of planning layout and urban composition, it has the typical combination of mixed house types with low cost housing by SHHA, BHC and Institutional low cost sitting in juxtaposition with medium and high cost housing. The area is serviced by a sub-centre, namely the Goodwill shopping mall which consists of a supermarket, a couple of pharmacies, a fast food place, a gym, four hair salons, a restaurant and a couple of dilapidated bars. It also has a couple of community primary and secondary schools surrounding it.

The adjacent G. West Industrial Site has a mix of industrial sectors that trade in building materials, motor vehicle centres, funeral undertakers, furniture distributors and clothing wholesalers. The industrial site is in turn close to a larger commercial mall, the Game-City Mall, which is on the southern edge of the city leading out towards to the south east district, as shown in figure 4 overleaf.

FIGURE 4: Plan of Gaborone West Phase 1



Source: Gaborone City Council Master plan (2002)

Figure 4 Legend:

LC	Low cost housing area
MC	Medium cost housing area
HC	High cost housing area

G. West Phase 1 is not one of the original residential areas of Gaborone. It was established in the early 80s by the Gaborone City Council (GCC) as a solution to the emergent urban squatter settlements in Old Naledi and Bontleng residential areas. The strategy was to absorb that population and future population from the planned G. West Industrial Site.

1.1.1. Current Housing Practice

Botswana since independence in 1966, is one of the fastest growing economies in Africa with a Growth Domestic Product (GDP) rate as high as 16% in 2002. A GDP growth rate that has since reduced to 8.3 % in 2006[2], due to a few challenges like the HIV pandemic and the single income dependency on diamonds. Although the GDP of Botswana has dropped, there are predictions that developing nations will continue to grow over the next three decades.[3] There are also good indicators for positive growth in Botswana due to the recent drive by the government to diversify the economy. Botswana is working on improving its industrial and manufacturing sectors as is evident in the recent introduction of diamond polishing industries.

However, with the growth Botswana has had to face some socio-economic challenges such as the growing need for provision of adequate shelter. Botswana is recently challenged by growing levels of rural to urban migration, with people seeking employment opportunities in the cities. As a result, one of the key challenges facing Gaborone today is the provision of land and shelter for its growing population. The greatest challenge stems from the low income sector, which cannot afford housing at current high market rates. The study views the low income sector as a major player in the residential building sector of Gaborone and Botswana. This view is shared by the Self Help Housing Agency (SHHA). According to an interview with the senior officer of SHHA low cost housing accounts for 60% of the housing

[2] http://www.gov.bw/minister's speeches/budget speech/feb06.

[3] Schlotfeldt, C. (2002).

population of Gaborone[4]. In view of rising housing demand, there is need for a sustainable solution towards the provision of low income housing.

Current urban low cost residential areas are characterised by poor urban fabric and poorly serviced neighbourhoods that lack facilities which are the result of poor construction practice. The houses of the poor tend to be hot in summer and cold in winter resulting in compromised health and reduced safety.

The study sought ways towards addressing the problem at its core. The objective is to facilitate the creation of sustainable housing development design practice through establishment of implementation frameworks at institutional level. This is premised from the fact that the Government of Botswana is the major player in the economy and the construction sector of Botswana. The main housing bodies SHHA and BHC are also linked to the government. Introduction of best practice in institutional housing sector would influence other housing sectors such as private developers.

In view of global environmental challenges, it is evident that there is a need to act sustainably at local level in order to avoid or reduce global impact. According to Ward, there is evidence that the building sector alone consumes approximately 40% of the world's energy.[5] Botswana cannot afford to continue practising non-sustainably and in isolation. She needs to heed the global concerns for reduction of global warming and depletion of resources, as expounded by the Kyoto Protocol Sustainable Declaration signed on December 11th 1997.[6] She also needs to deliver on the Millennium Development Goals' objectives that include the need to eradicate poverty, ensure environmental sustainability and global partnership for development.[7]

Sustainable development will lead to a number of socio-economic spin-offs for the country. There are benefits to various national sectors including home owners, house occupants and

4 Siele, P. (2005).

5 Ward, S. (2002).

6 http://unfccc.int/resource/docs/conv/cp/kpeng.html jun07.

7 http://www.un.org/millenniumgoalsjun07.

the Government. These include better residential communities, improved indoor comfort, reduced energy consumption and thus overall reduced energy demand, savings in running costs of households, reduced impact on the environment by the construction sector, reduced investment on national programmes to reduce environmental impacts and better urban microclimate.

The study supports the idea of acting responsibly locally to curb both local and global challenges. Botswana has put in place some sustainable development strategies such as the creation of National Conservation Strategy (NCS) under the National Conservation Strategy Agency (NCSA) which is responsible for environmental policy and legislation. The agency has set up the Department of Environmental Affairs (DEA) which is responsible for implementing the strategies and programmes.

However, sustainable development is lagging behind in the housing and construction sector. While there is a dedicated department for housing namely, the Department of Housing which falls under the Ministry of Lands and Housing, there is no agency that has been put in place to ensure sustainable development in housing. The Department of Housing was formed in 1994 as a result of the recommendations of the Organisation and Methods Report of 1991. It was set up to establish development programmes towards adequate, safe and sanitary shelter for all. Its responsibility is to design and formulate housing policies, monitor and guide local authorities in both urban and rural context and both private and public sectors. Its activities and duties are guided mainly by the National Policy on Housing and the General Orders, Circulars and Directives that are issued from time to time. The National Policy on Housing provides the policy direction for the housing sector.[8] While the government orders of 1996 were established for the management of pool housing.[9]

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[8] http://www.landsandhousing.gov.bw/mar07. In line with Vision 2016, the policy aims at the provision of decent and affordable housing within a safe and sanitary environment. The major thrust of the policy is fourfold;

1. to change the emphasis of Government from home provision to facilitation in the various settlements in partnership with other stakeholders;
2. to channel more Government resources (and emphasis) to low and middle lower income housing in both urban and rural areas;
3. to promote housing as an instrument for economic empowerment and poverty alleviation; and

The Department of Town and Regional Planning was established in 1972 and is responsible for all national physical planning matters. The Department operates 2 offices, a headquarters office in Gaborone and a northern regional office in Francistown. It was established due to a need to manage the rapid urbanisation and growth of rural and urban centres. Its functions and operations are guided by the following policies and guidelines[10]:-

1. The Town and Country Planning Act of 1977, which is the principal legislation that governs its mandate to provide orderly development.
2. The National Settlement Policy of 1998 which provides guidelines and long term strategies for land use and infrastructural planning developments.
3. The Urban Development Standards of 1992 that guide urban infrastructural developments to ensure affordability of plots and access to resources.
4. The Development Control Codes of 1995 provide regulatory framework for land use activities and ensures quality control in developments.

The Building Regulations Board under the Ministry of Works and Transport are currently reviewing building regulations and it is hoped that sustainability and resource efficiency will be addressed. The board membership is made up of stakeholders such as BOTEC and it is hoped that their participation will bear positive influence noted above. This initiative is viewed positively as regulation is cited by professionals and by the Energy Efficiency and Conservation (EECBS) Pre-project study.

The exclusion of sustainability in developments filters to implementation of projects. The Department of Buildings and Engineering Services (DBES) under the Ministry of Works and Transport is responsible for implementation of institutional housing projects. This department also operates without a strategy for integration of sustainability framework.

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to foster a spirit of partnership with the private sector and all major employers in home development and facilitating home ownership

9 http://www.dpsm.gov.bw/policy.nsf/june07.

10 http://www.dpsm.gov.bw/policy.nsf/june07.

1.1.2. Sustainable Housing

Sustainable housing calls for the understanding that housing development is larger than the house unit. Housing development should transcend to planning level and the treatment of the surrounding landscape. The study demands a paradigm shift from the present urban development of the city which was inherited from colonial times. That is, planning that tended to imitate urban planning and building forms for other climates and other economic contexts. These inappropriate plans have resulted in poor environmental conditions, poor housing developments which block summer breezes and the winter sun.

The paradigm shift also targets at appropriate sustainable housing construction design and techniques rather than evident add-on environmental features that are added to standard housing plans. It calls for housing development to be perceived as a system, with an enabling structure that is economically, socially and environmentally responsive and is suitable for the context. This integrative approach to housing development will make housing work in many complementary ways. It acknowledges that the design of any building derives from considered responses to various aspects such as climate, technology, culture and the site.

These principles are embedded in bioclimatic architecture which purports to integrated architectural design systems that are related to context, sustainable use of resources and use of alternative technologies.[11]

According to Jones, the principles of bioclimatic architecture call for a holistic treatment of the building envelope, determining the role of its different components such as design, materials, appliances, its consumption levels, maintenance and its final disposal. [12] Although the principles of bioclimatic architecture are relatively known, their successful application is still limited both in scope and distribution in Botswana.

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[11] http://www.geocities.com/ResearchTriangle/Facility/8776/Pag01I.htm.jul07.

[12] Jones, D. L. (1998).

Current housing development has lost the core concepts of indigenous Tswana architecture. In part due to the colonial era and also the haste to provide urban housing. However, even post colonial era, Botswana's urban communities and recently rural communities have continued to copy conventional "modern" houses in the quest for acceptance. This has resulted in the loss of adequate well conceived housing and settlements.

Traditional Southern African housing and settlements were developed by indigenous systems that took into account the culture and the support systems (fauna, security, hierarchy of spaces including public, semi-public, private and semi-private, communal, entertainment and play). Post colonial and modern housing development practitioners tend to develop housing separate from the "whole". According to Schumacher, modern man did not view himself as part of nature but as an outside force which was destined to dominate and conquer it; forgetting that this has implications for the continued existence of humanity.[13]

The consequences of continued lack of good practice in housing construction are:-

a. Poor indoor environment that has resulted in increased need for resources, especially increased demand for energy for household functions. The increased energy demand taxes already limited and dwindling resources such as fuel wood and electricity for the country.
b. Poor neighbourhood planning impacts on sociological aspects of outdoor living which is traditionally favoured by the warm climate and communal culture.
c. Unsustainable choice and use of resources such as land and building materials.

It is evident that housing construction contributes to environmental problems such as increased carbon emissions and negative impact due to global warming by way of processing of construction materials, transportation of materials and through the building's life cycle. According to earth-pledge, architecture presents a unique challenge in the field of sustainability considering that construction projects typically consume large amounts of building materials and produce tons of waste. It further calls for the need to weigh the

[13] Schumacher, E. F. (1974).

preservation of buildings that have historical significance, against the desire for the development of newer, more modern one.[14]

Botswana is not isolated in this respect. Despite being signatory to the international protocols for sustainable development, the majority of developing countries are slow in the adoption of sustainable housing development. In fact, even some of the developed countries are still struggling with implementation of sustainable development. According to Herde, some of the globally noted obstacles include increased urbanisation costs, lack of knowledge among practitioners and lack of land zonings and planning guidelines for sustainable urban habitat.[15] Local research has come up with similar feedback. The Energy Efficiency and Energy Conservation in the Building Sector of Botswana (EECBS) Pre-project found that a few stakeholders in Botswana have delved into energy efficiency and sustainability however the initiatives are not translating to the ground to either professionals or the public at large.[16] Some of the identified barriers are that few residential buildings are designed by architects and the poor standard of construction practice. There is need for integration of policies, strategies, plans, guidelines and standards. As a result the system lacks incentives that could encourage changes and encourage information dissemination.

The EECBS Pre-project study suffered some limitations due to resource constraints and was confined to commercial and institutional buildings. The reason cited was that the latter were selected for their high energy consumption levels. This resulted in the omission of the residential sector which is a major stakeholder in the building construction sector of Botswana. This omission has led to this research study.

[14] http://www.earthpledge.org/mar06.

[15] Herde, A. (1996).

[16] Tumisang, H. etal. (2005).

1.2. THE RESEARCH PROBLEM

The problem of this study emanates from the noted gap regarding the integration of sustainability and resource efficiency into the residential building sector of Botswana. While there have been a few research demonstration projects in housing, few have been adopted into housing developments. According to research findings by Gibberd, while there is an urgent need to solve social and economic problems, environmental degradation, and implement and integrate sustainable development into mainstream practice; the implications of sustainable development for buildings and the construction industry in the developing countries are not well understood. [17] There are noted barriers both at local and regional level that inhibit sustainable development.

The aim of the study was to provide a sustainable implementation framework that will lead to quality, affordable, sustainable and resource-efficient housing. The study targeted institutional housing conducted through implementing bodies such as the Department of Buildings and Engineering Services (DBES), the Botswana Housing Corporation (BHC) and the Self Help Housing Agency (SHHA). The intention is to influence their plans and strategies. Any positive change in their developments is expected to have significant impact on other housing developments in the country.

This study holds the view that the key towards improved housing developments for Botswana is through the creation of enabling mechanisms and as economics is pivotal to our modern world, such a mechanism should take into account viability and affordability. According to Schumacher attempts at sustainable housing developments should be weighed against their affordability to ensure that they make economic sense.[18]

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[17] Gibberd, J. (2003).

[18] Schumacher, E. F. (1974).

1.3. KEY OBJECTIVES

The objective of this study is to come up with a framework that will facilitate sustainability and resource efficiency in institutional housing practitioners.

A framework that is part of a process towards creation of enabling structures within the implementation system for the support of best practice in the institutional low cost housing sector of Botswana, towards the improvement of the quality of housing and a contribution towards the reduction of the negative impact by the housing construction sector on the environment.

The framework can be used as a tool at various stages of the institutional structure including the macro, meso and micro levels.

1.4. THE STUDY

The motivation of the study is articulated in the statement of the problem, section 1.2. The omission of the residential sector by the EECBS pre-project gave opportunity for further research into housing, and in particular low cost housing which is the largest section of the residential sector. The research problem was found to be in line with focused developmental trends for Botswana, such as the nation's Vision 2016 and the National Housing Policy of 2000. Chapter 7 of the National Agenda 21 singles out the promotion of sustainable human settlement development, eradication of poverty and hunger, greater equity in income distribution, and human resources development. It further stresses the need for an enabling environment, in conformity with sustainable development principles. A national assessment was conducted at the start of the eighth National Development Plan (NDP) 8 (a 6 year plan spanning from 1997/98 to 2002/03 financial years) which revealed that previous population growth patterns, levels and types of production processes combined with unsustainable consumption patterns were placing severe pressure on life supporting capacities of the country.[19]

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[19] http://www.un.org/esa/earthsummit/botsw-cp.html/mar06. Botswana drew up a national settlement strategy with eight programme areas that needed to be developed towards fulfillment of the 1992 Rio declaration. These were to be used to set priorities for the country and form the basis of the NDP objectives. They include the following providing adequate shelter for all, improving human

Under the NDP 8 and the current NDP 9, a number of national initiatives were set up including the National Housing Plan. Table 2 below, shows the status of some of the planned activities in housing.

TABLE 2: Status on Planned Activities

ACTIVITY	**STATUS**
1. Revised Policy on Housing	*The policy was revised in the year 2000. However, the new policy skims over the subject of sustainability. Refer to appendix section.*
2. Finalisation of the National Housing Plan	*In progress*
3. Completion of the National Settlement Policy	*In progress. Some issues are still under debate and some articles were published in the recent Gazette newspaper.*
4. Introduction of the concept of Sustainable Cities Programme	*Outstanding*

Source: The Government White Paper no. 2. (2000) and The Botswana Gazette Newspaper (2006)

The National Housing Plan saw the creation of the SHHA scheme. The scheme was developed to take care of squatter settlements in the cities. It has been instrumental in improving the housing stock from the squalor of self allocated settlements to a regulated planned activity with a dedicated body to facilitate the process. However, the scheme has some identified limitations which are listed below:-

1. It is not accessible to all the poor as the stipulated income bracket does not qualify most of the poor.

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settlement management, promoting sustainable land use planning and management. Also promoting integrated provision of environmental infrastructure, namely water, sanitation, drainage and solid waste management, promoting sustainable energy and transport systems in human settlements, promoting human settlements planning and management in disaster prone areas, promoting human resources development and capacity building for human settlements development. The implementation of the national settlement strategy included the roll out of the National Housing Policies of 1981 and 2000, and a number of programmes for the delivery of shelter such as the Self _Help Housing Agency (SHHA), Land Serving Programme, the Capacity Building in Shelter provision, Improving Human Settlements Management and developed the National Settlement Policy (NSP).

2. Although norms and standards have been stipulated under the Government White Paper of 1982, regulation and controls in terms of the quality and standard of the houses that get built has been difficult as plot-owners are not forced to adopt the SHHA designs.[20]
3. SHHA officers do not have the knowledge and capacity for the implementation of sustainable and resource-efficient housing.
4. SHHA designs themselves have no consideration for sustainability and energy-efficiency.

According to the CORDE Shelter study, the population of Botswana has more than doubled in the last 20 to 30 years; at an annual growth rate of 3.4% and urbanisation and the urban housing population like wise.[21] It further states that the quality of housing, materials and construction for Botswana were still guided by the Urban Development Standard and the Building Control Regulations of 1981. The Urban Development Standard mentions the need for correct orientation of plots especially as the size of residential plots has been considerably reduced. This initiative would support sustainable orientation of housing with regards to the climate.

According to Larsson, there is need for affordable standards that allow for upgrading of affordable housing over time. He discourages the introduction of typical building codes that are used in developed countries, for developing countries.[22]

As already noted by the EECBS Pre-project, there is a gap in the efforts of the housing sector of Botswana between the different players such as the planners, professionals, researchers, institutional bodies and the implementing bodies like DBES, BHC and DOH. This means that while the government at macro level has signed protocols for sustainable development, the meso and micro level are continuing to function in a "business as usual" manner.

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[20] Larsson, A. (1988).

[21] CORDE Shelter Study Report. (1994). Approximately 10% of the urban housing provision for the country has been absorbed by peri-urban villages, Tloweng and Mogoditshane.

[22] Larsson, A. (1988).

The study's output in the form of a framework is not a solution but rather a tool that can be introduced for roll out in stages in the short, medium and long term for integration into the existing system. Short term initiatives bear little or no cost, while medium term initiatives have slightly more cost with a short pay-back period. However, long term initiatives have higher initial costs coupled with longer pay back period but maximum benefits. Medium to long term initiatives may not be suitable for sustainable low cost housing due to affordability. The tool facilitates the housing developer to make decisions at an early stage.

Another output is a proposal guideline booklet on sustainable and resource-efficient housing construction for Botswana. The proposed booklet is for implementation by the Botswana Technology Centre (BOTEC) through the Sustainable Housing Project which commenced in March 2006 and is due to complete in 2009.

1.5. THE SIGNIFICANCE OF THE STUDY

The study addresses a relatively neglected area of research in the housing construction sector of Botswana. This is in part due to limited knowledge and information, inadequate policies and in part due to perceived high cost if integration of sustainability and resource-efficiency by the construction sector.

Botswana inherited a fairly poor undeveloped country from the colonial era, and the housing sector was no exception. Colonial urban housing was conceived purely to sustain a labour force that was to support the small urban development and industry. Post independence there have been a lot of housing developments, however the majority of housing developments were based on colonial structures that are unsustainable. The housing sector continues to operate on inherited structures. For sustenance, these structures need to adapt to suit their environment and be part of the collective effort for the greater good.

Sustainable housing can only be achieved through collaborative effort. According to Gibberd, the briefing and design stages of the development of buildings play a key role in establishing the extent to which buildings and construction support sustainable development, yet there is little support to ensure that sustainable development is addressed and incorporated in the briefing and design of buildings in developing countries.[23]

Research of this nature supports taking advantage of natural elements such locally and readily available materials and the abundant sun shine for the betterment of its infrastructure and quality of life of the people. This is possible through lessons taken from indigenous systems and precedent studies from the region and the international community. According to the South African Energy White Paper, when planning urban areas, all passive measures must be exhausted before active measures in building technology can be intelligently introduced.[24]

Currently Botswana depends on the dwindling regional electricity power supply from Namibia and South Africa. There is need to pay more attention to the dynamics of demand for electricity or for inconspicuous energy consuming services.[25] According to Southerton, that is critical in the development of socio-technical systems and two important components need to be observed namely, indoor environmental comfort and the changing role of domestic appliances.[26]

The significance of the study is further supported by the EECBS Pre-project report which states that there is limited research on resource efficiency in the country, while the country is landlocked, drought prone and has limited resources.

1.5.1. Delimitations of the Study

Due to constraints of time and resources, the data collected for this study was limited to urban low cost housing of Gaborone, with one area of Gaborone studied in detail. The bias towards urban low cost housing is because it is the area of highest concentration of housing

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[23] Gibberd, J. (2003). The construction sector is the world's largest employer, proving approximately 28% of all industrial employment, it constitutes half of the total national capital investment and it accounts for half of the raw material taken out of the earth's crust.

[24] The South African Energy White Paper. (1998).

[25] Shove, E. and Warde, A. (2001).

[26] Southerton, D. (2005). There is a lot of energy consumption by routine of what is considered normal and ordinary practice. It is noted that people do not really consume energy; they consume the services; for instance heating, cooling, lighting, showering, entertainment and appliances which are made possible by infrastructure.

and it is observed that in Botswana the people tend to import new concepts from the city to their villages. This sector of housing will enable the initiative to achieve more with little intervention.

The study centred on urban housing, with neighbourhoods treated as urban settlements. This way housing is treated as part of a whole system. The study noted that current urban settlement planning of Botswana is transport centred due to an industrial and economic focus and that SHHA emphasizes mainly on the physical structure; building materials, their durability and economy. The SHHA systems tend to and neglect the social and functional qualities.[27]

1.6. ORGANISATION OF THE STUDY

Chapter 1: The Problem and It's Setting

This part of the study gives a detailed account of how the research was developed and it outlines the layout of chapters presented in the study.

Chapter 2: The Research Methodology

This chapter sets out a detailed plan of how the study intends to investigate and execute the problem, including stages of work from establishing the research design, the procedures and analysis of the findings towards reaching a conclusive effort.

Chapter 3: Literature Review

Through literature review a desk study of related information on the subject of study was gathered, including local literature, government documents such as policy, legislation, strategic documents and plans. The review was extended to regional and international precedent studies to gain insight on the subject. The review was intended to inform the next stage of survey research and the overall study on pertinent issues that are needed to address the problem of study and lead to development of specifications for the framework.

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[27] Larsson, A. (1988). The government provides a serviced site and only modern materials are allowed as they are provided for in the policies. Through the SHHA loan scheme, the plot-holder can obtain building material loan and technical assistance.

Chapter 4: Situational Analysis

This chapter reviews the status of housing development in Botswana with the aim of distilling the causal effects. A survey research was conducted in a specific representative population frame of Gaborone. First observation studies were conducted to investigate the infrastructure and its relation to the surrounding urban environment. Then a two-pronged survey was conducted through user questionnaires and stakeholder interviews. The intention was to consult extensively with all stakeholders.

Chapter 5: The Framework

This chapter established the framework for sustainable and resource-efficient institutional housing development for Botswana.

Chapter 6: Conclusions and Recommendations

Conclusions to the study were drawn from findings, analysis of collected data and the established framework and recommendations identified for future research.

1.7. THE DEFINITION OF KEY TERMS

The following definitions and terms are specific to this research and were included for clarity.

1.7.1. Sustainable Housing Development

It is development that aspires to the principles of sustainable development which is a continuous process of maintaining a dynamic balance between man and the eco-system. It applies to the construction cycle from extraction and beneficiation of raw materials, to planning, design and construction of building or infrastructure, until final deconstruction and management of the resultant waste.

1.7.2. Bioclimatic Architecture

Bioclimatic architecture is the application of flow energy principles and climate characteristics of a region in the design, construction and management of houses with an aim to achieve thermal comfort with minimal conventional energy input. The basic components of this design principle include orientation of the house, optimizing direct natural light and using thermally efficient building materials. Passive solar design means achieving indoor thermal comfort with nature. Energy flows naturally while the building responds passively with little or no imported energy. Where additional energy is needed there is support for renewable energy sources.

1.7.3. Energy Efficiency

Energy efficiency is the use of energy wisely in order to accomplish the same task; sustainable use of energy to ensure that social, environmental and economic aims of sustainable development are supported. The intention is towards energy saving and the reduction of negative impact on the environment.

1.7.4. Low cost Housing

A low cost house is typically a house that is affordable to low income earning households. The Botswana Housing Corporation (BHC) classification for low-cost housing refers to housing ranging from P80, 000.00 to 160, 000.00. The typical BHC low cost house comprises of a kitchen, bedroom, living room and combined shower and toilet.

While the SHHA low cost house ranges in size from one room to four rooms, and is located on subsidized plot costing BWP 3, 000 and measuring 370 square metres. To qualify for a SHHA plot the individual should earn in the region of BWP 300 to BWP 3, 000. Once allocated a plot, the expectation is for one to put up an incremental house unit from 2 roomed to a four roomed house. The development should have a toilet and in most cases it is a pit latrine, due to lack of funds to connect plumbing. The developments are approved through the Gaborone City Council SHHA office.

Once the plot is paid in full, a title deed is issued and then the owner may develop the house according to their economic status. Financial entitlement for the low income earner is for loans of up to P20, 000, depending on their salary. Due to financial constraints, most people develop one room at a time and expand the household as their economic circumstances change. The tendency is to occupy one room and rent out one or two rooms to supplement their income. This practice is accepted by the councils and encouraged as it has helps to reduce squatter settlements.

1.7.5. Thermal Comfort

It is the indoor state described by a temperature zone, termed the thermal comfort zone. Thermal comfort zone is a range of internal conditions where most people will feel neither hot nor too cold. It is described by the following indices:-

- Temperature range
- Humidity range
- Metabolic rate
- Amount of clothing worn by occupants
- Ventilation rate

1.8. SUBPROBLEM ONE AND HYPOTHESIS ONE

1.8.1. Poor Building Practice

Despite the global call for sustainable development, there is little change and no systems for implementation of sustainable housing development in Botswana. There is need for enabling mechanism to facilitate or guide the integration of sustainability and energy efficiency into the current housing development system.

1.8.2. The Hypothesis

Current housing projects deplete natural resources and increase national energy requirements. Unsustainable consumption patterns are placing severe pressure on life supporting capacities of the country.[28]

1.9. SUBPROBLEM TWO AND HYPOTHESIS TWO

1.9.1. Precedent studies

There is need to identify suitable aspects of sustainable, energy-efficient design that can inform future sustainable housing developments and the specification of the framework for sustainable housing development in Botswana.

1.9.2. The Hypothesis

Conventional housing is compromised by ignoring of good qualities found in vernacular architecture, bioclimatic architecture and best practice examples.

1.10.KEY ASSUMPTIONS

The following are the key assumptions of the study and they are discussed in detail in the literature review:-

a. Quality housing is a basic human need in the same way as shelter, food, clothing and health.

b. The dwelling is the established meaningful relationship between people and their environment.[29] The house is part of the space surrounding it, and cannot be treated in isolation.

c. Sustainable development should be supported by adequate policies and implementation structures.

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28 http://www.un.org/esa/earth summit/botsw-cp.html/mar06.

29 Norberg-Schultz, C. (1988).

Chapter 2

METHODOLOGY

2.0 INTRODUCTION

According to Leedy, the methodology of a study is a means by which the research seeks to address the identified problem; by identifying ways of acquiring data and controlling it and how it seeks to extract meaning from the data.[30] For the purpose of this study research methodology is achieved through research design and through set procedures for data collection and analysis, leading to conclusion. There are three major components of the methodology:-

1. Literature Review, which was conducted through a desk study of all documents related to the study including previous research, reports, newspapers, internet, maps and Government documents on housing and energy covering guidelines, policy, legislature, strategic plans, implementation procedures and current practice.
2. Situational Analysis, a two pronged survey consisting of an observation study of selected low cost houses and research survey involving affected stakeholders. The latter was conducted through data collection by application of user questionnaires and stakeholder interviews; which were then analysed and assessed.

[30] Leedy, P. and Ormrod, J.E. (2001). Research methodology directs the whole endeavor – critical decisions are made and organizing, planning and directing the whole project. The methodology controls the study, dictates the acquisition of the data, arranges them in logical relationship, sets up a means of refining the raw data, contrives an approach so that the meanings that lie below the surface of those data become manifest, and finally issues a conclusion or series of conclusions that lead to an expansion of knowledge.

3. Research outputs, the sustainable and resource-efficiency framework and the proposal booklet on guidelines for sustainable and resource-efficient low cost housing.

These components are detailed in the following sections of this chapter as to inform on how the study was executed.

2.1 LITERATURE REVIEW

The study used the literature review process to gather existing information in order to gain a better understanding of the problems raised by the study in section 1.2 and to support the hypotheses raised in section 1.8 and 1.9 respectively. Literature review was applied to identified categories including planning, housing design, materials, construction and technologies with a view to establish the extent of the problem, barriers and possible interventions.

Literature review also informed the research about the type of additional information and data that was needed for the survey research.

2.2 SURVEY RESEARCH

The survey research formed the data collection and assessment part of the study. Its focus was on addressing sustainability and resource-efficiency in low cost housing. Quantitative research methods were employed to gather data within a determined set of parameters. These include building practice and implementation framework, urban settlement and planning aspects, sustainable design aspects, appropriate materials, appropriate energy and appropriate installations.

Through observation studies and survey research, quantitative information was obtained and summarised through statistical analyses. At times a combination of both quantitative and qualitative research methods was used depending on the type of data that was collected. The different stages of the survey research process are discussed in the next section.

2.2.1 Observation Studies

Observation studies were used to establish the physical state of low cost housing, against a set check list consisting of characteristics and or parameters which would help address the problem of study. The objective was to investigate particularly issues pertaining to urban planning and design (especially investigating the suitability and sustainability of the settlement and design), construction methods and building technology used for various categories of low cost housing of Gaborone. Observation studies were conducted through case studies; through a selection of both bad and good practice examples for benchmarking purposes. According to social research methods, a case study is seen as a comprehensive study of a social unit be it a person, group of persons, an institution or a community. It is a way of organising social data so as to preserve the unitary character of the social object being studied.[31] Due to resource constraints already mentioned in the delimitations section 1.12, local case studies were selected from the selected study area, G. West Phase 1. The choice of case studies was based on accessibility and similar context. The following sets of aspects were used to observe each case study:-

1. Technical Assessment

Technical assessment of low cost housing in its setting; taking into perspective the overall settlement, the house in relation to other houses, the street, supporting structures such as accessibility, transport, shops, work, entertainment and recreational activities. These were identified as key criteria for sustainability and resource-efficiency in line with integrated sustainable development process. Such housing addresses the key sustainability indicators, namely social, economical and environmental.

The following parameters were identified and their specific applications were conducted under the case studies in chapter 4:-

a. Urban settlement planning
    i. Plot location and orientation.
    ii. Relation of plot to neighbouring sites and surroundings.
    iii. Nature (business/residential/size/height/structure) of neighbouring plots.

[31] http:// www.social researchmethods.net/april06.

iv. Plot densities in the area.

v. Relation and distance from nearest basic services (water, electricity, sewerage, telephones, shops and transport.

b. Housing design and development

i. House design aspects including open-building/adaptability, replicability, place-making, community and affordability.

ii. Sustainability of design, technology and materials.

iii. Thermal comfort considerations.

iv. Commonly used materials, their properties and the role of materials towards building performance and the achieving of sustainable, energy efficient low cost housing.

c. Resource efficiency

The study views energy as an integral part of the building conceptualisation process. Hence there is need for considerations for energy source(s), materials, equipment, appliances, energy consumption and their impact on the environment. Evidently, low cost housing tends to use very little energy due to limited finance. The tendency is for mix use of energy types. The study focuses on the basic functions that need energy such as cooking, lighting and water. It aims to establish:-

i. Types of energy sources, mix use energy considerations, availability and sustainability of the source(s).

ii. Energy consumption patterns and related costs.

iii. Lighting considerations, for natural and artificial lighting and the type of light fittings.

On average, the low income household cannot afford to cool or heat their houses.

2. Observed Problems and Barriers

The observed reluctance to adopt sustainability and resource-efficiency at various levels of the housing development system, that is from planning, implementation and operational levels. The barriers were identified in the current housing development system that impact on housing and building practice. The aim was to gain understanding of the problems and inform the solution in the form of the proposed framework.

2.2.2 The Survey

The survey was designed to address specific areas of the research problem. While observation studies were an audit of current housing, survey research was intended to shed light on the nature and extent of the problem. Information was gathered on the settlement, housing design, construction, user information was found invaluable. People's views on the housing were taken as lived experiences that needed to inform the framework.

Two survey research methods were employed namely, user questionnaires and stakeholder interviews with various stakeholders at various levels of responsibility including policy, planning and implementation.

Face to face interviews were preferred in both cases, in order to establish a rapport with the potential participants. This ensured better response rates. Another advantage of this personal approach was that ambiguous answers were clarified immediately and follow-up information requested on the spot.

User questionnaires were designed to be fully structured questions on the dwelling and socio-economic aspects. The stakeholder interviews were of carefully identified stakeholders from the public and private construction sector. The role of stakeholder interviews was to address the technical aspects of the research problem. As a result stakeholder interviews were structured differently, using semi-structured interviews. That is, having standard questions yet allowing a few individually tailored questions and discussions.

2.3 RESEARCH OUTPUTS

2.3.1 Framework

The key output for the research is the developed framework model for sustainable and resource-efficient low cost institutional housing for Botswana.

The framework is proposed to inform the implementation of institutional housing thus improving building performance, indoor thermal comfort, construction practice and reduce negative impact on the natural environment.

2.3.2 Proposed Booklet

The study output is translated into a proposal for a future booklet on Guidelines for Sustainable and Resource-Efficiency in Housing Construction for Botswana. The study proposal for a booklet is towards addressing the issue of limited information on sustainability and resource-efficiency in the country and to start a trend of information dissemination of research findings.

The booklet is targeted for dissemination to public sector stakeholders including the Department of Buildings and Engineering Services (DBES), Gaborone City Council (GCC), SHHA, Department of Housing (DOH), Department of Town and Regional Planning (DTRP), Botswana Housing Corporation (BHC) and the University of Botswana.

The booklet is to be developed further through a future programme by BOTEC namely, the Sustainable Built Environment Programme.

2.4 ASSESSMENT

Central to the study was the question of how measurable was the phenomenon of sustainability and resource-efficiency. Certain measurable criteria were developed to determine the sustainability of a design, the level or state of resource-efficiency of a design and its performance. These were based on well researched concepts or strategies such as the bioclimatic principles and the regionally developed criteria for sustainable building life cycle in the context of developing countries such as the Sustainable Building Assessment Tool (SBAT) (2001).[32]

[32] Gibberd, J. (2003).

The study was limited to these specific criteria which were to achieve optimum thermal performance of the house for improved indoor comfort through adequate design. Through observation studies and survey research the study was able to yield quantitative information that could be summarized through statistical analyses. These were made possible through prescribed population sample sizes and parameters.

Chapter 3

LITERATURE REVIEW

3.0 INTRODUCTION

Literature review provided background information for the study and conveyed knowledge and ideas that have been established on the topic including strengths and weaknesses. It further allowed for "comparison, lived experiences and what could be learnt from those experiences". [33] This literature review was guided in its focus by the problem of study laid out in section 1.2.

Through literature review the study reviewed various aspects that relate to sustainability and resource-efficiency for low cost housing including planning, design, materials, energy, conservation and thermal comfort. For in-depth understanding, the study reviewed local, regional and international precedent studies. As Botswana has limited published literature the information from neighbouring countries like South Africa was found to be invaluable, as they shared a similar background with Botswana.

3.1 ANALYSIS OF HOUSING SITUATION

The premise of this study is rooted in the understanding that the role of Science and Technology is to help us to find solutions to society's basic functions and or needs. This literature review identified ways in which science and technology can be used to probe and

[33] Landman, T. (2000).

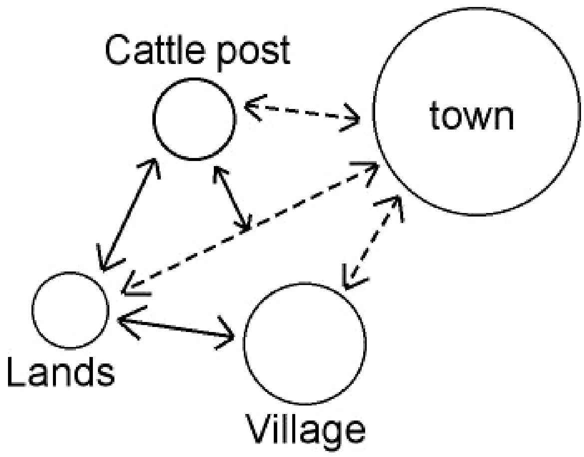
improve the quality of low cost housing in a sustainable manner. The key identified areas of impact were planning, design, materials and associated resources such as energy. The study sought to understand the existing housing development structure and practice of Botswana. Further, to establish what has been done in these areas with regard to sustainability, resource-efficiency, and indoor comfort for low cost housing with the view to draw lessons from past experiences.

3.1.1 Botswana's Residential System

Botswana's low cost housing is borne of housing that was a "quick fix" solution to housing due to the population explosion experienced in the eighties, due to the diamond boom. This resulted in a multiple residence system with the average Motswana having at least three dwelling places; an urban house to facilitate one to go to have access to work, a rural home, a lands dwelling and or a cattle post "moraka" house.

Hence the low cost house of the colonial era were a single room which was either a stand alone or semi detached type meant to be used as temporal accommodation for working season, because the workers kept a substantial home in the village. The multiple residence system is illustrated for the study as figure 5 below.

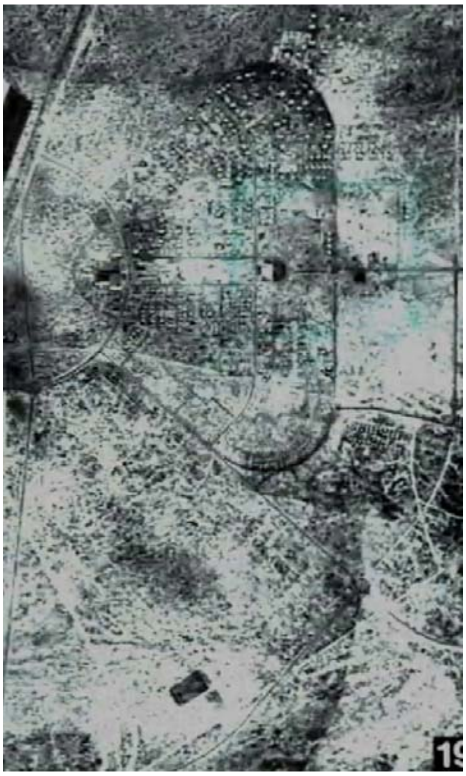
FIGURE 5: Multiple Residence System



3.1.2 Demand for Housing

The housing situation has been impacted on by an unexpected increase on the housing population. Botswana was a British protectorate republic governed from Mafikeng in South Africa until independence in 1966. At independence, Gaborone, the capital city of Botswana was borne out of a need to establish an administrative capital for central government of Botswana. The city was then planned for a population of 30 thousand people. Nobody anticipated the present population of more than 250 thousand people of diverse cultures, as a result of the advent of the diamond mining boom. Mining resulted in a population explosion and a subsequent need for housing that was not catered for in the original plans. The highest need for housing is in the urban areas, as a result of rural to urban migration. Figure 6 below is the 1966 map of Gaborone consisting of just the central portion of the current city.

FIGURE 6: Aerial Map of Gaborone



Source: Department of Surveys and Mapping (1966)

3.1.3 Development of Low Cost Housing

Post independence, the low cost house was improved by the introduction of institutional housing, through the privatization of the BHC's accelerated housing schemes. BHC housing schemes are characterised by the single house on a single plot in the main. Although a few medium to high density houses have been developed for some institutions.

Through the SHHA land settlement and housing provision act, self built incremental two roomed houses with pit-latrines were established. These were allocated on a single subsidized non- serviced plot. SHHA housing is serviced by dirt roads and the basic amenities are water and electricity, provided at street level. The plot owner has to connect from there.

Another type of low cost house has developed recently parallel to SHHA incremental housing, namely the two and half low cost housing consisting of two rooms and adjacent flushing toilet. It is built by private home owners who are usually not having access to funding.

The planning and design of low cost housing and its immediate surroundings is generally left to the individual. The SHHA Office of the Gaborone City Council has little impact in terms of regulation; they conduct site inspections at different levels of the construction. This practice has led to problems in terms of development and quality control. Housing development tends to be concerned mainly with the provision of shelter, meeting the SHHA specification of 35 to 45 square metres of building. Further, the planning and layout of the plots tends to be aimed at cramming as many plots as possible with little regard for the resultant quality of houses and surrounding environment.

The problem transcends to design. The majority of low cost housing tends to be hot in summer and cold in winter, as they are not designed to cater for the climate of Botswana. Another contributory factor is that the majority of housing is not designed by architects. Due to lack of proper legislature and regulations the majority of houses, especially low and medium cost housing are designed and supervised by technicians and draughtsman who offer the service at much reduced rates to the architects. Botswana is currently addressing this problem through a parliamentary act.

Also the development of housing needs to integrate sustainability in infrastructural development and resource efficiency so as to ensure that present needs without jeopardising future generations. Evidently, settlement and building trends are changing with more people moving into cities and as more materials and technologies are developed. Also more people are buying property and settling in the city. Botswana needs constantly address changing systems in view of local and global developments and challenges.

3.2 SUSTAINABLE HOUSING

"Simple interventions such as orientation and adding a ceiling to an existing house yield huge benefits to the occupant. Not only will they spend less on energy but will improve indoor air quality and the spin off is less emissions of greenhouse gases e.g. carbon dioxide to the earth's atmosphere." [34]

The study intends to facilitate sustainable and resource-efficient low cost housing surrounding built environment, in line with assumption 1 of this study which considers housing as part of a whole system and Kaltz's "new urbanism concept". According to Kaltz, architecture is concerned with both the pieces and the whole. It applies principles of urban design both at local and regional level and is defined by diversity, pedestrians, scale and public space.[35] It calls for the structure of bounded neighbourhoods to be applied regardless of locality and then the entire city should be designed according to similar urban principles" Housing development should be structured by public spaces with discernible edges having diverse circulation systems that support movement.

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[34] http://www.itdg.org/html/energy/docs48/bp48/may05. According to Klunne, two key interventions; identified for South African low cost housing; 1. All new low cost houses should feature at least the principles of passive solar design, supplemented installation of the ceiling. 2. Existing houses need to be made more energy efficient by installation of ceiling or application of insulation material.

[35] Kaltz, P. (1994).

According to Rapoport the house cannot be seen in isolation from the settlement but must be viewed as part of the total social and special system which relates to the house, a way of life, settlement and even the landscape.[36] These views purport to sustainable development of housing that is in harmony with its surroundings. Understanding the relation of the house and its settlement or the surrounding built environment leads to understanding the factors that inform and influence housing development. Rapoport states that, “the site does not determine form but rather, the effect of the site tends to be cultural and dependent on the goals and ideals of the people or the designer”.[37] The understanding of house form and the elements that relate to it such as socio-cultural aspects like the family structure, the social structure, and cultural influences will lead to sustainable housing development.

The degree of sustainability and resource-efficiency of housing has social, economic and environmental effect in the housing construction sector. Hence, the study reviewed low cost housing in its context.

3.2.1 Indigenous Systems

The notion of sustainable development of the whole is deeply entrenched in indigenous architecture and culture of Batswana (the people of Botswana). In Botswana, indigenous settlements are planned as part of the whole village. Settlements are planned as a semi-circular collection of buildings, around a communal central space known as the “kgotla”. The kgotla is a public to semi-public space used by the clan for gatherings. Each kgotla is governed by a chief.

Under the kgotla are smaller units called wards. Each ward has a small kgotla called a “kgotlana” or “patlelo” which is used by surrounding families for traditional gatherings like funerals and it doubles as a safe play area for the children. A typical village layout is depicted in figure 7 overleaf.

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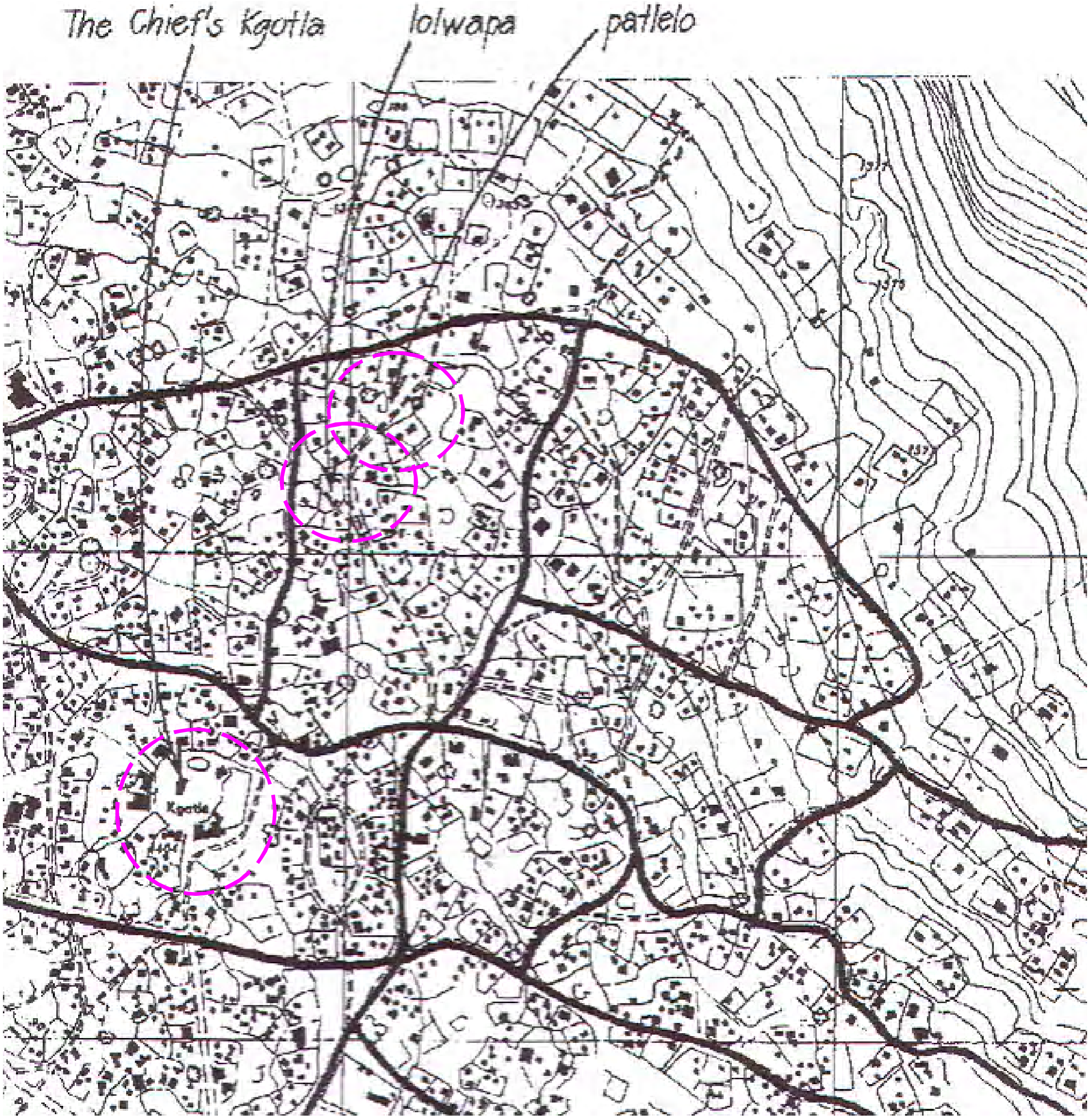
[36] Rapoport, A. (2002).

[37] Rapoport, A. (2002).

FIGURE 7: Typical Tswana Village Neighbourhood



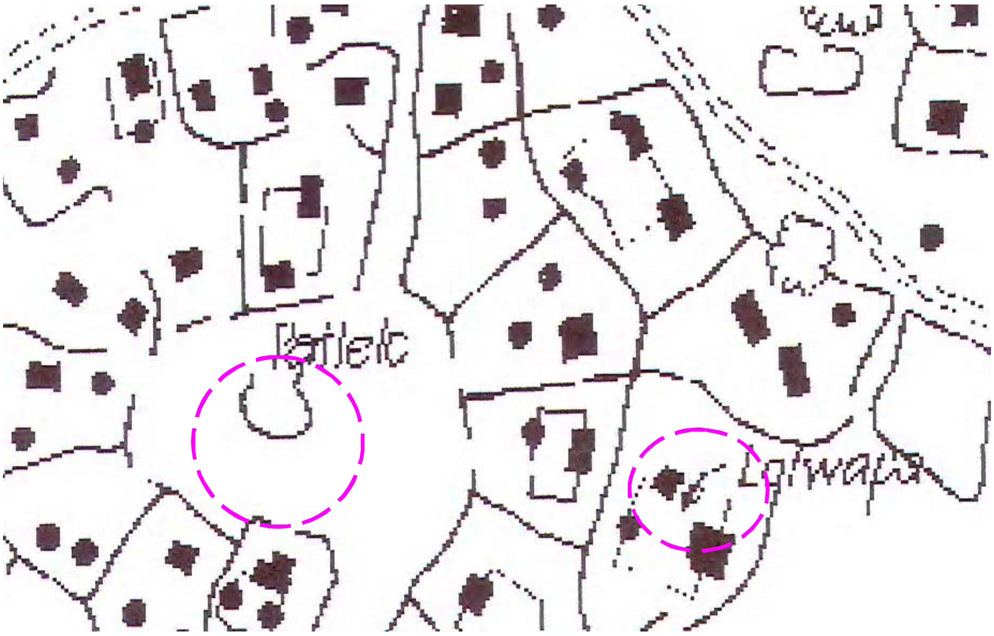
Source: Moapare, V. (2002)

The character of neighbourhoods was primarily achieved through interaction and visual connections between residential and public spaces in between.

According to Rapoport, the physical factors such as climate, construction materials and technology become the modifying factor to the settlement or form. The role of climate as modifying factor is important as it affects the building system. Vernacular housing form responded well to climate. The effects of temperature, humidity, wind, rain, radiation or light are important for building performance and for the achieving of thermal comfort.

Construction materials, structure and technology make possible the enclosure of space; while organisation, systems sequence and hierarchy of spaces make possible the function. The Tswana housing has variety of spaces in support of outdoor leaving, for example the lolwapa courtyard space shown in figure 8 below.

Figure 8: <u>Hierarchy of spaces</u>



Source: Moapare, V. (2002)

Characteristics of the indigenous settlement:-

a. Large plot (compound) of approximately 1, 500 square metres.
b. Detached buildings
c. Separation of functions – sleeping, living areas, external cooking, storage

Tswana indigenous housing responds to nature, the climate and culture, in much the same way as bioclimatic design. Orientation, thermal mass, materials and design layout, openings, overhangs and screens are manipulated for optimum design.

While there are several variations of Tswana housing which occur by region and sometimes by function, the variations generally appear as minor changes in form, materials and decoration. The deviations are mostly due to availability of materials, climate, culture and urbanisation. Figure 9 below is a typical Tswana homestead from Gabane Village.

FIGURE 9: Typical Tswana Housing

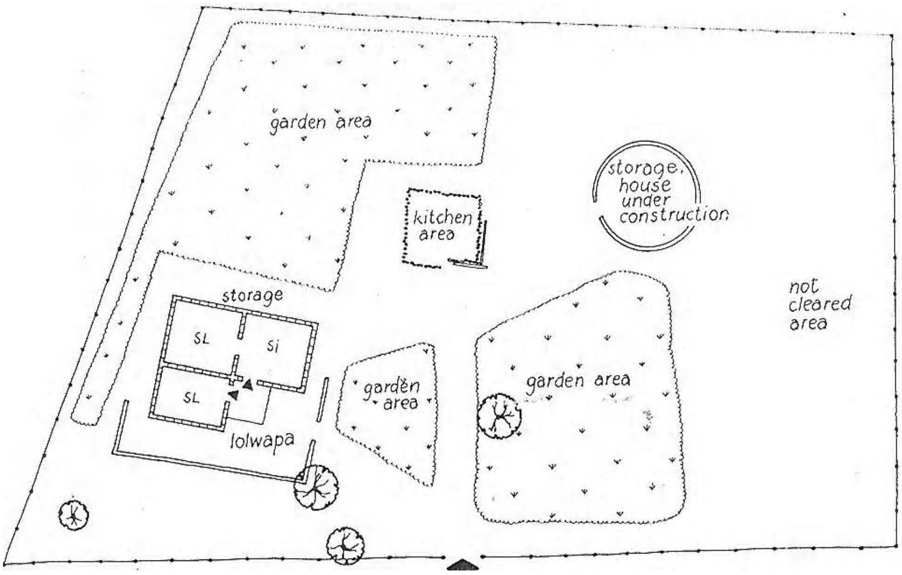
Source: BOTEC Photo Library (2007)

Characteristics:-

a. Local materials
b. Thermal mass from mud blocks
c. Insulation from roofing thatch
d. Few and small windows
e. Roof overhang shades the building
f. Lolwapa courtyard semi private space
g. Wind breaker from landscaping

Changes to the homestead have occurred due to changing social and economic dynamics, as depicted in figure 10 overleaf.

FIGURE 10: Housing Transition



Source: Larsson, A. (1988)

Characteristic changes are noted below:-

This household has an additional three roomed compact house and new landscape aspects like the gardens. However, it does not lose the positive aspects such as:-

- Orientation
- Compact plan
- Hierarchy of spaces
- Sun and wind protection

While culture is not static, positive aspects need to be adapted to suit changing circumstances. In the case of Botswana a number of factors contributed to the loss of these aspects, including perceptions on status due to the belief that conventional housing is better than indigenous housing.

Other factors are poor availability and affordability of local materials, high maintenance costs. For example, thatch is very scarce due to poor rainfall. Another contributing factor is that there is limited research on indigenous materials and techniques. The EECBS pre-project report states that one of the major drawbacks towards achieving sustainable energy efficiency in the country is the lack of information on local building knowledge and materials. Hence, one of the outputs of this study is the proposed booklet on sustainable and resource efficient low cost housing for Botswana. The booklet proposal is intended to encourage further research into housing and local building resources.

3.2.2 Current Settlements

The majority of settlements and housing developments are currently structured by plot-density, services and transport. This was caused by rapid development as a result of diamond mining which started in the eighties. Some of the negative aspects of current urban settlements include:-

a. Master plans provide civic and communal spaces without amenities.
b. Communal spaces lack “shared space” quality and have been resigned to become football pitches.
c. City isolated from housing; only used by day.
d. Lack of provision of spaces for children to play.
e. Outdoor living areas not integral part of planning and design.

3.2.3 Housing Transformation

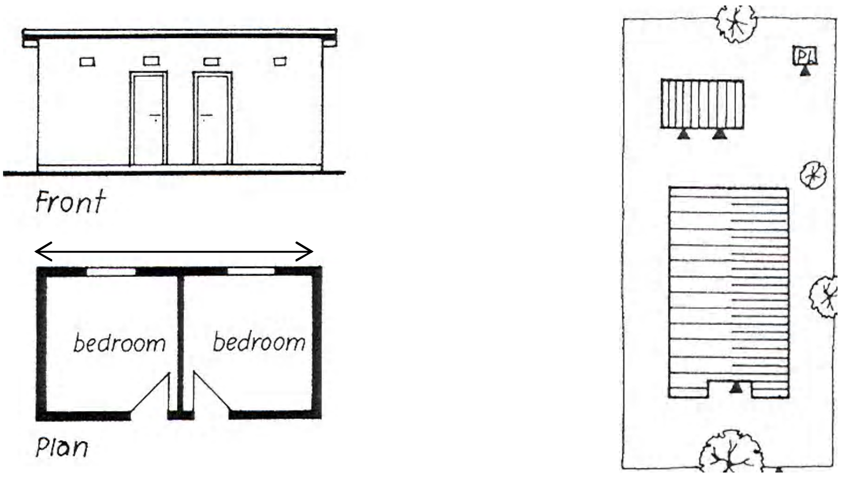
Conventional housing introduced many changes to change the form of housing in terms of implementation, design, materials and technology. General deviations from the indigenous house include:-

a. Incremental housing with the majority of housing starting as a single room which is used for sleeping, living. Most of the cooking is done outside on an open hearth.
b. Incremental housing starting with a 2-roomed house that grows incrementally to a 3/4-roomed house. This type of housing either separates some of the functions like sleeping and living. The majority of 2-roomed housing uses the second room for rental purposes.

Both use a pit latrine that is provided separate from the house.

Figure 11 overleaf shows a typical SHHA two-roomed house and land usage.

FIGURE 11: SHHA Housing



Source: Larsson, A. (1988)

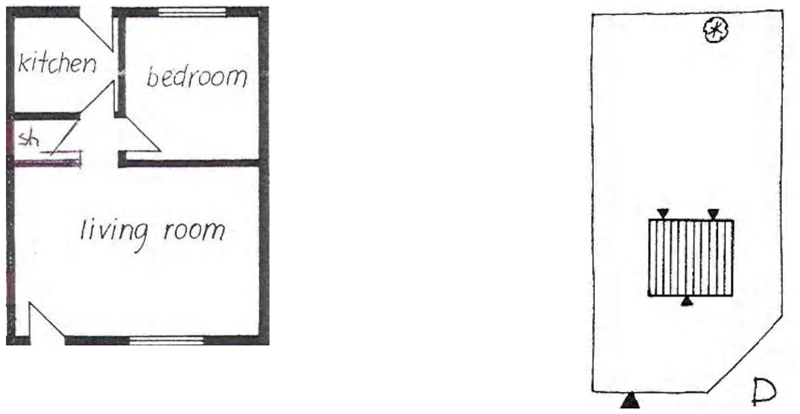
Characteristic changes:-

a. No lolwapa or dedicated outdoor space.
b. Shallow roof overhang.
c. Bigger windows.
d. Poor insulation from roofing material

BHC low cost housing on average provides a fully serviced plot, water, electricity, sewerage and tarred roads. The plots are standard with low cost plots ranging from 400 to 600 square metres. The plots are crammed together to minimise the cost of servicing. There is little regard for plot orientation.

The BHC Low Cost House is an upgraded version of the SHHA house. It ranges from 35 to 45 square metres. It has designated sleeping, living and cooking spaces. Basic low cost housing consists of 3 or 4 -roomed housing having separate functions for sleeping, cooking and combined shower and toilet as shown in figure 12 overleaf.

FIGURE 12: <u>BHC Housing</u>



Source: Larsson, A. (1988)

BHC houses use more conventional materials and techniques than SHHA houses. However, they have the following discrepancies:-

- Bare site. No provision for outdoor living spaces and no shaded areas.
- Shallow overhangs.
- Bedrooms open directly into the living room – privacy compromised.
- Font entrance opens directly to the weather.

Several factors contribute to the lack of sustainability and energy efficiency of the SHHA, BHC and the majority of conventional low cost houses. Housing developments are more concerned with density and costs. Poor consultation between planners and implementing bodies has resulted in poor quality of settlements especially in the urban areas. Housing developments and plans are concerned mainly with the physical aspects and conforming to outdated standards.

According to Larsson, current low cost house fails in terms of functionality, “although it has constraints of space and is often over-crowded, the urban low cost house lacks hierarchy of spaces that support outdoor living for socializing with family and friends”.[38]

The design of low cost housing is lacks simple features that improve function and are suited to the climate. Improvements identified are protection from the weather in the form of deep reveals and verandah and use of landscaping to shade the building and outdoor space.

[38] Larsson, A. (1988). Modernisation of low cost housing mainly involves building materials and to some extent the use of space. Insufficient indoor space in connection with increased demand for more indoor space often leads to over-crowding for large families in the low income bracket

According to de Silva, as far as qualitative aspects of housing are concerned, a satisfactory residential environment is expressed in both physiological needs such as comfort, protection from elements etc. and psychological needs such as community and family life.[39]

3.3 LOCAL PRECEDENT STUDIES

Local precedent studies were investigated in order to understand housing practice of Botswana.

3.3.1 The Sustainable Energy Africa Project (1981 to 1985)

The Sustainable Energy Africa (SEA) project was aimed at developing the policy framework for the energy policy of Botswana, through strategy and implementation frameworks that feed into the NDP. The project integrated all sub-sectors and was highly interactive involving the majority of stakeholders. It sought to upgrade SHHA housing through introduction of simple affordable passive solar design strategies and educating the SHHA dwellers. Simple design and retrofit ideas were demonstrated.

The project output was the development and production of the Botswana Renewable Energy Technology (BRET) Project booklet.[40] These developments were never adopted by SHHA developments. The study interviewed one of the SHHA officers who confirmed that the current SHHA low cost house design is not conceived of sustainability and energy efficiency due to lack of knowledge and capacity. However, SHHA is keen to adopt the skills provided they are properly implemented.

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[39] http://www.hdm.lth.se/TRAINING/Postgrad/HD/papers/2002/Feb 06.

[40] BRET Project. (1985).

3.3.2 BOTEC Demonstration Projects

A number of energy efficient housing demonstration projects have been implemented by the Botswana Technology Centre (BOTEC) that demonstrate various technologies and techniques aimed at improving the performance of houses in a climate such as Botswana.

a. BOTEC Managing director's residents at plot 8530, built in 1989 to demonstrate resource efficiency and conservation.
b. Semi detached low cost housing at Broadhurst plot 10911/12/14/16, built in 1990 for staff members.
c. BOTEC Experimental Staff Houses in Gaborone West (G. West) phase 1, built in 1992 to cater for staff accommodation and to demonstrate the use of alternative materials for walling and passive cooling techniques.
d. BOTEC Guest house at Broadhurst Plot 8511 built in 1994.
e. Motsomi Residence, a private dwelling for a client. Designed by BOTEC in 2003.

The projects researched on various strategies and a number were demonstrated in different housing units as listed below:-

- Plot orientation – east/west orientation of plot and buildings.
- Compound arrangement – neighbourhood concept.
- Compact plan and semi detached housing.
- Deep overhangs and courtyards.
- Insulated ceiling.
- Trombe wall to achieve stack effect for ventilation.
- Solar water heating.
- Active heating of floor slab.
- Evaporative cooling.
- Solar control devices such as using vegetation, overhangs, parapet walls.
- Rain water harvesting for water recycling.

The G. West BOTEC Experimental Staff Housing was studied in detail in this study and used to benchmark the case studies in section 4.2.4.

3.3.3 The EECBS Pre-project Study

Recently, the EECBS Pre-project study investigated the status quo regarding the performance of building in Botswana with regards to energy. The pre-project study was a feasibility study to the main project. The objective of this project is to influence and demonstrate energy efficiency in buildings in the country. The main project has selected to target the larger sector of buildings in the commercial and institutional sector, such as offices and schools. The sectors were selected due to limited resources as they are the largest consumers of energy (electrical energy). Some of the key findings of the EECBS pre-project study are listed below:-

a. Not enough documented information on sustainability and energy efficiency in Botswana.
b. Limited knowledge, skills and research on the subject.
c. Lack of awareness. on the subject.
d. None coordinated efforts by various stakeholders.
e. Poor response to demonstration projects.

3.3.4 Mitigation

In an attempt to improve research uptake, BOTEC is reviewing its focus. It is departing from consultancy type projects to technology partnership research. BOTEC strategy is to partner with stakeholders such as Department of Housing (DOH), Department of Building and Engineering Services (DBES), Department of Environmental Affairs (DEA), Department of Energy (DOE), Botswana Housing Corporation (BHC), Local Government developers to deliver industry based research and improve technology transfer. Through the Sustainable Housing Programme, BOTEC is to conduct specific research into housing that is suitable for Botswana.

DOE has also embarked on building energy programmes. The EECBS project includes the implementation of building energy efficiency guidelines that are to be incorporated in the current building developmental codes; construction of a couple of demonstration buildings (office buildings); short term training for professionals and the development of university curricula on energy management systems.

Positive mitigation strategies involve integrated effort that cuts across all levels. Hence, the proposed framework for institutional housing while not a conclusive solution facilitates implementation and can be adapted to suit the situation.

3.4 OTHER PRECEDENT STUDIES

The study values the findings of precedent studies to inform the research. Due to limited information in Botswana, precedent studies were taken from neighbouring South Africa which shares similar background and climate. Also, South Africa was selected for its experience in sustainable development and energy efficiency initiatives. Post apartheid in 1994, South Africa has conducted numerous housing projects from the Rural Development Programme (RDP) to integrated housing system.

South Africa adopted a sustainable housing development process that targeted policy, legislation and implementation. They established the National Agenda 21 which defined the local sustainable development agenda, objectives and strategies. The South African White paper, defines sustainable development as that development which ensures that environment and development are not two separate issues, but are strongly linked.[41] This approach led to the creation of Integrated Development Plans (IDP) which emphasised the need for cross-sectoral planning, community participation, capacity building and putting in place institutional enablers. Government formed partnerships with the private sector and research institutions such as CSIR to address planning and housing development practice. Some of the outcomes of the partnerships are the CSIR Blue Book and the Green Book that were recently revised to create the Red Book of 2000, a book on Guideline of Human settlements and Design.

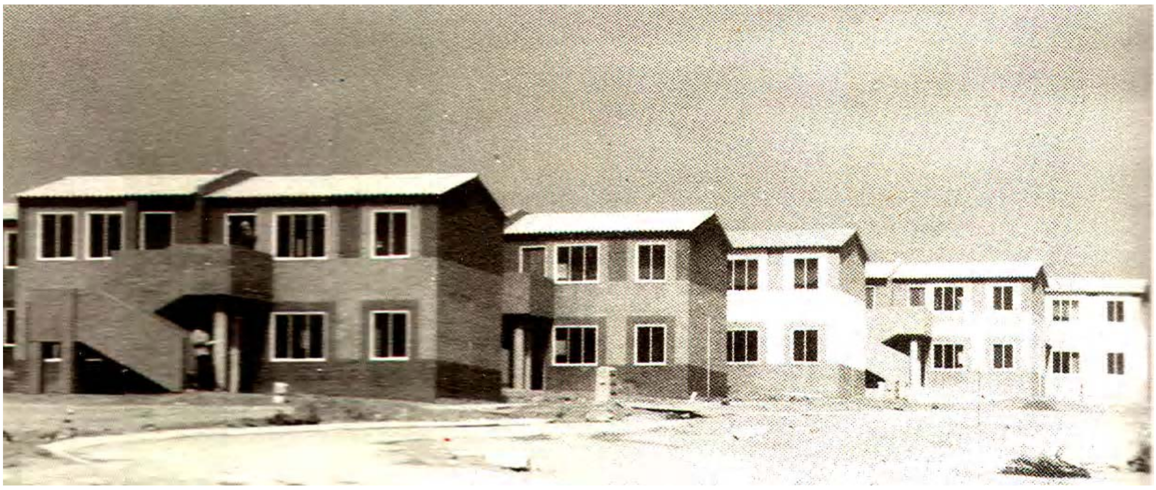
[41] The South African Energy White Paper. (1998). All natural resources found in the environment should be integrated into planning, and buildings conceived in a way that their form, location and structure permit energy saving. When planning urban areas, all passive measures must be exhausted before active measures in building technology can be intelligently introduced.

A number of low cost sustainable housing developments initiatives were attempted all over South Africa, including the Missionvale project in Port Elizabeth, the Midrand Ecocity and Cato Manor in Durban. Few of the projects have explicitly incorporated passive solar design features while the majority of projects selected certain features and applied them to the norm. The commonly applied features are insulated ceilings or solar water heaters and thermal mass. Some case studies were studied for benchmarking purposes.

3.4.1 The All Africa Games Village (1999)

The All Africa Games Village was a combined project for Eskom and Rand Water. It is situated in Alexandra Township, Johannesburg. The location is a previously disadvantaged area of Johannesburg. A total of 1, 799 low cost housing units were completed, together with a school and a shopping centre. The units range from 32 to 50 square metres in size. Figure 12 below shows some of the housing units from the village.

FIGURE 13: <u>The All Africa Games Village</u>



Source: Urban Seed Update, vol. 1 no.2. (2002)

The project incorporated a number of innovative design components including as detailed below.

Sustainable Urban Planning/Design features:-

- North facing, staggered units.
- Insulated ceiling.
- Light colored roof strategies to avoid heat gain in summer.
- Dark colored walls to absorb heat in winter.

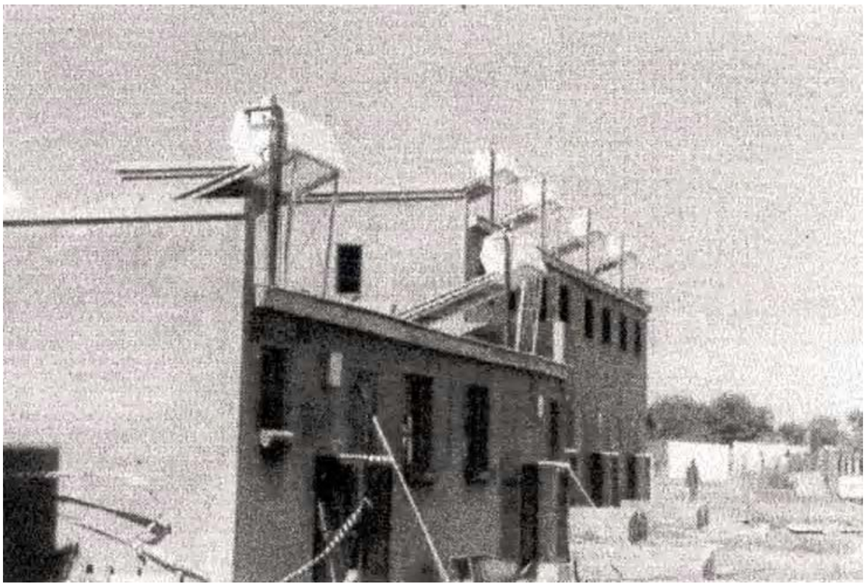
Alternative technologies/techniques:-

- "Energy saving" light fittings.
- Water and sanitation techniques; low flush toilets, short hot water pipes, vertical geysers.
- Pre-paid metered water and electricity.
- Awareness campaigns and user education.

3.4.2 The Moshoeshoe Ecovillage (2002)

The village, shown in figure 13 below, was conceived as a demonstration project owned by the Moshoeshoe Housing Association.

FIGURE 14: <u>Moshoeshoe Ecovillage</u>



Source: Urban Seed Update, vol. 1 no.2. (2002)

The project was funded by SIDA and the Sol Plaatjie Municipality of Kimberley, South Africa. It consisted of 13 units that are part of the larger Hull Street Project which is planned to consist of a total of 2500 units.

The eco-village demonstrated the innovative eco-block concept with double storey units, agriculture and open spaces and a number of sustainability initiatives as discussed below.

Innovative Urban Planning/Design Components:-

- Compact semi-detached row houses.
- A unit for a disabled person.
- Combination of 3 and 4 row houses.
- Rental units with option to buy after 4 years.

Sustainable design features:-

- Insulated ceiling.
- Roof overhangs.
- Light coloured roof to avoid heat gain and to reflect heat away from the house in summer.
- Dark colored walls to absorb heat in winter.

Alternative technologies:-

- Solar water heating.
- Grid interactive solar.
- Wind electricity in the office building.
- Mix use energy using LPG gas for cooking.
- Energy saving light fittings.
- Water and sanitation techniques, including rain water harvesting, grey water recycling and dry sanitation and urine diversion.

3.4.3 The Asian New-town Concept

The concept incorporates environmental design to low cost housing.[42] It was developed in phases over the last 20 years. It started practically by planning good orientation to the sun and wind, and recently shifted in response to greater demands for quality and more-effective use of space. Good environmental design was found to be a combination of design considerations, including:-

[42] Yueng, Y. (1983).

a. Building orientation.
b. Human scale
c. Street-block design
d. Street architecture
e. Handling of topography and the landscape.

The orientation of the building to the sun and wind was found to be of major consideration, followed considerations for noise of traffic. The strategy is to achieve good design through natural and simple interventions such as earth mounds to shield low-rise buildings, and use low rise buildings in turn to shield high-rise buildings further away from the roads. Great emphasis is placed on the more meaningful use of communal spaces at different hierarchical levels, while preserving desirable visual effect and a good sense of enclosure in between buildings.

The concept allows for slow integration of sustainability. Guidelines are revised continuously for instance space between buildings. Recently high density was found to be necessary to conserve land. Higher plot ratios are achieved from the construction of larger flats while maintaining the same population densities.

3.4.4 Houses Without Heating Systems

These houses are built 20 km south of Goteborg in Sweden. They were designed by EFEM Architects and built by Egnahems-bolaget, as part of a research project involving Chalmers University of Technology, the Swedish Council for Building Research (Formas), Lund University and the Swedish National Testing and Research Institute. Figure 15 overleaf shows some of the features.

FIGURE15: Low Energy Terrace Houses

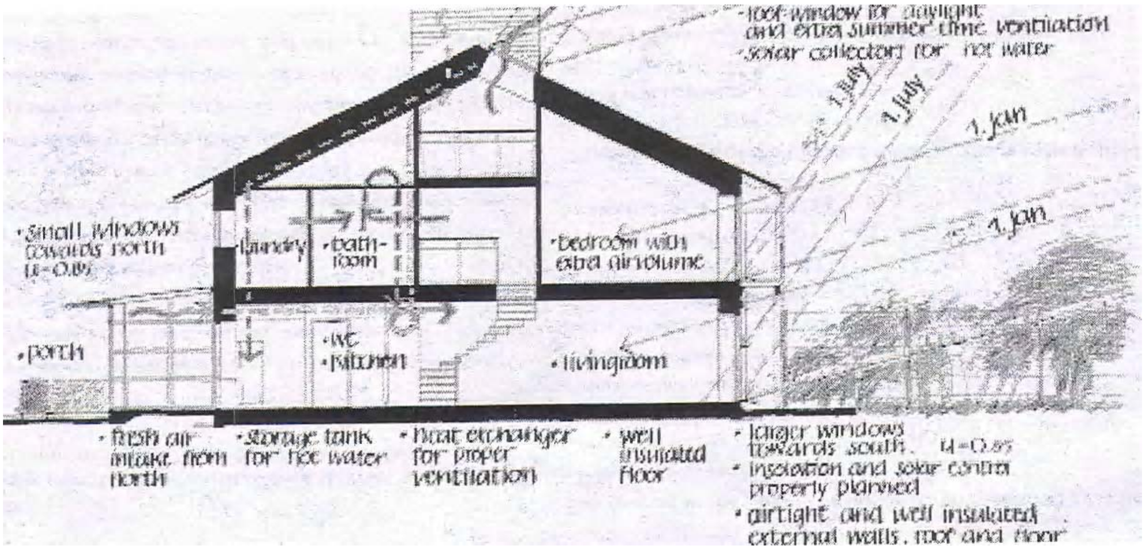
Source: http://www.goteborg2050.se/jul05

The houses were designed to provide a pleasant indoor environment with minimal use of energy. The traditional heating system has been replaced by a heat exchanger and a very well insulated building construction. Part of the design process was to reduce building costs and reduce running costs for the occupants.

Innovative design components include:-

- Narrow/deep plan (5 x 11 metres) framed construction.
- Terrace plan, with courtyard.
- Few external walls; well insulated and airtight.
- Insulated floors.
- The south courtyard façade has large windows, which maximises solar access.
- Projecting eaves protect balconies in summer.
- Roof window above staircase designed for light and summer ventilation, shown in figure 16 overleaf.

FIGURE 16: Section of Terrace Houses



Source: http://www.goteborg2050.se/jul05

The building envelope constructed within strict regulated compliance standards. All had to comply to strict thermal values as follows:-

- Wall, framed construction with 430 mm insulation. U value = 0.10 W/m2K,
- Floor, concrete slab on 250 mm insulation. U value = 0..09 W/m2K
- Roof, masonite beams with 480 mm insulation. U value 0.08 W/m2K
- Windows, three pane windows, with 2 metallic coats and krypton fill. U value 0.85 W/m2K. Energy transmittance = 43%, Light transmittance = 63%
- External door, U value 0.80 W/m2K

Alternative technologies/techniques:-

- Additional heating for extreme weather conditions: the supply air is heated by exhaust air in a heat exchanger, plus internal heat loads such as occupants, appliances and lighting. Heat from occupants = 1200 kWh/year and heat from lighting & appliances (fridge, freezer, cooker etc.) = 2900 kWh/year
- Solar water heating (500 litre tank), with 5 square metres solar collectors per house, with electricity (immersion heater) for back up.

- Ventilation is achieved through a supply and exhaust unit with a counter-flow heat exchanger providing 85% heat recovery. In summer the heat exchanger can be turned off and the house ventilated with only exhaust air and open windows
- Building costs were estimated to be normal. Any additional costs from extra insulation and air tightness, heating system and ventilation were designed to be recovered through lower operational costs and energy savings.
- Estimated energy use per year:-
    - Household electricity = 2900 kWh
    - Water heating = 1500 kWh (rest by solar collector)
    - Appliances = 1000 kWh (fans, services, pumps)
    - Total energy per year = 5400 kWh

Goteborg was one of the first cities to participate in the European Healthy Cities programme, using the Healthy Cities Framework. The city uses a number of frameworks to bring sustainable development to various players and to obtain buy-in. As the city lacked structures and process, neighbourhood demonstration projects were developed first to show the application of a multi sectoral process. Once the structures were put in place, in 1994, the framework was applied at city scale. The Healthy Cities Framework led to the development of Plans and multiple Policies that are geared to the overall framework for action. While the 4 principles of the Natural Step were used as guiding document for development of the Environmental Policy which ascribes the development of an environmental management system for the city and the Local Agenda 21 was used to frame local initiatives. This city is renowned for having one of the most broadly focused approaches to sustainable development.

3.4.5 The Energy Efficient Residence (1981)

The house was built by the National Association of Home Builders Research Foundation Inc., in Damascus, Maryland, as part of a research and demonstration project. It was designed to include as many energy-saving ideas as possible and to determine the cost savings of each idea. The open plan design allows for natural heat circulation and ventilation, as depicted in figure 17 and 18 below.

FIGURE 17: Upper floor Plan

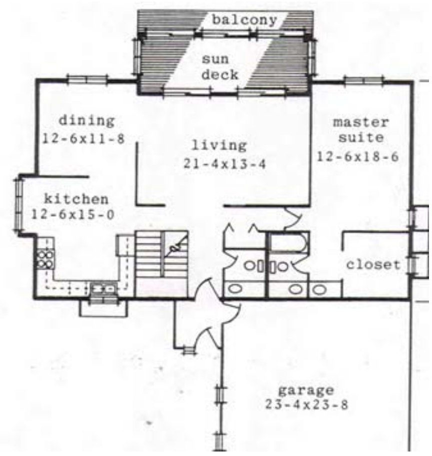
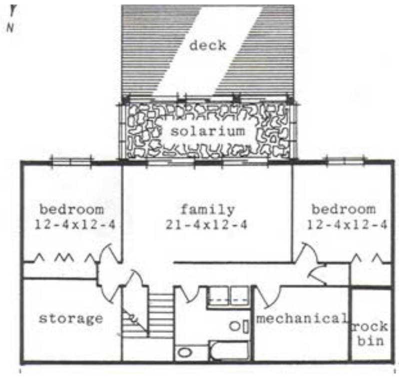


FIGURE18: Ground floor Plan



Source: Energy Guide

The two storey house has many large, south facing windows that allow direct, indirect and a sun space for passive solar heating. Every room faces south for direct heat gain except for kitchen (as heat is produced in cooking) which faces the cool north-east corner.

Innovative aspects of the design include:-

a. A compact, well insulated and air tight building envelope.

b. Reduced heat loss - earth sheltered garage and non-living spaces on the north and thermal shutters for windows.

c. Re-use of exhaust air through design for high return – living room ceiling sloped upwards.

d. Sunspace enhances liveability and contributes to heating.

e. Air lock vestibule for infiltration.

f. Natural ventilation - cross ventilation from windows and ceiling vents.

Figure 19 and 20 overleaf illustrate the ventilation strategies for winter heating and summer cooling.

FIGURE19: Winter Solar Heating

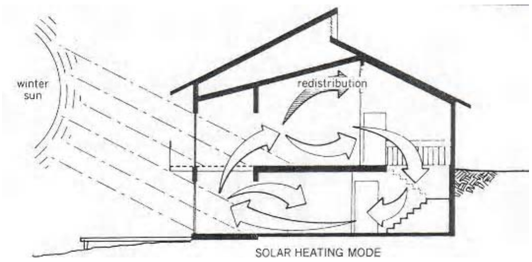
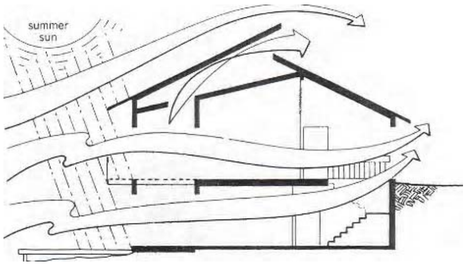


FIGURE 20:Summer Natural Ventilation



Source: Energy Guide

Alternative/innovative technology:-

a. Earth-coupled heat pump, extracts heat from a 300 foot deep well in winter, and acts as heat sink in summer.

b. Heat exchanger used for air-to-air recovery of heat and from heat of appliances such as showers and washing machines.

c. Rock bin provided for indirect heating – proved to be a failure.

3.5 SUMMARY OF PRECEDENT STUDIES

"Housing policy should be moving towards economic, standardized and flexible but quality design; designs that will enrich the quality of life of the inhabitants, and must in the end serve the somewhat primitive and eternal needs of man for a home".[43]

Current housing practice in Botswana is generally unsustainable and lacks holistic integration of efforts by various stakeholders. Botswana can learn from regional and international precedents. There are valuable lessons from precedents such as the Asian new-town concept that can be adapted for Botswana. Policy and legislation needs to be supported by plans and strategies that facilitate implementation. It is vital for Botswana to establish frameworks for integration of sustainable development into existing structures. The study identified some well known frameworks for applying sustainable development.

[43] http://www.hdm.lth.se/TRAINING/Postgrad/HD/papers/2002/Feb 06.

3.5.1 The Ecological Footprint

It is a visual tool developed by the University of British Columbia in 1993, which measures the ecological carrying capacity of the community, city, region, country or world to sustain the given population. It enables the calculation of sustainable levels of resource consumption and waste discharge.

3.5.2 The Natural Step

The framework was developed in Sweden by a cancer specialist Karl-Hendrik Robert in 1995. The Natural Step supports sustainable development of a cyclical nature. It purports to sustainability that requires systems thinking rather than short term linear Thinking and encompasses long term thinking in consumption and waste disposal.

3.5.3 The Local Agenda 21

A planning framework that enables local government to apply sustainable development based on the Rio Conference on Environment and Development adopted in 1992. It is a global plan for sustainable development. It is adopted and adapted by various governments. As a tool, it assists local government in development plans and strategies. The framework encourages multi-stakeholder participation and private public partnerships and ascribes to a process rather than an outcome.

3.5.4 Healthy Cities

This framework was conceived in Toronto, Canada in 1984, at the Beyond Health Care Conference. It was established in recognition that most of the factors affecting health are outside the health sector itself. It is a three pronged multi-stakeholder process involving vision, analysis and action. These are applied differently by various cities to support integrative decision-making.

Developed countries have gradually established policies and plans that cater for sustainability and resource efficiency. Frameworks for sustainability are either already in place or are being implemented. The majority of these countries are using a mix of frameworks to create enabling structures at meso and micro levels.

Denmark, Sweden, the Netherlands, Australia and the UK have adopted some guiding principles and legislation to guide infrastructural development and some of the achievements are listed below. [44]

a. Pedestrian-oriented city centres, mix use streets; arterial streets are larger and finished in asphalt, while the bicycle and pedestrian routes are narrower and mostly cobbled.
b. Tram service; environmental friendly system of transport
c. Reduce cars in the city centres and fewer parking lots in new office developments
d. Building regulations and codes that include sustainability and energy efficiency
   - Set U-values for various aspects of the building envelope
   - Assessment and resolution of designs prior to building through building simulations to check for energy consumptions and cost savings and water conservation.
e. Renewable energy sources are on the increase especially for water heating. The change is supported by some of the consumption of the European Union figures. According to Sustainable Energy Ireland Report (September 2003), as much as 57% of the energy consumption by the home is for space heating, followed by water heating(25%), lighting (11%) and Cooking (7%). The Report supports the change to renewable energy sources such as solar, wind, wood, refined biofuels (pellets and briquettes) and biogas.

According to automatedbuildings.com, Denmark and the European Community are advanced in sustainable design and that much of the milestones made by Denmark are due to excellent demonstration projects that are supported by national budgets. Programmes such as the European Union (EU)'s Thermie projects have a dual focus on affordable demonstration projects that are supported by funding of experimental housing; and excellent publications that seem to be influencing the designers. [45]

The general view is that private sector and industry have limited margins and too much competition to allow them to shift towards sustainability and energy efficiency. A paradigm

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[44] http://www.automatedbuildings.com/news/jan00.

[45] http://www.automatedbuildings.com/news/jan00.

shift in implementation of sustainability and resource efficiency as demonstrated above has positive effects. It results in a ripple effect to housing and in particular low cost housing. Countries begin to have low cost housing that is developed holistically like the Milton Keynes project in the United Kingdom.

3.6 DEVELOPMENT FROM PRECEDENT STUDIES

According to the Southern African Trade Research Network (SATRN) Working Paper No. 4 entitled, "Construction and Related Services in Botswana", the construction sector in Botswana has played a significant role in economic growth. Its share of GDP ranged from 7.6% In 1990/91 to 6.1% in 1999/2000.[46] These figures compare favourably with industrialised countries whose share of construction in total GDP ranges between 5% and 7%. The share of construction sector in total paid employment ranges from 12.5% in 1993 to 10.5% in 1999.[47] The share of employment in construction is higher than in most Organisations for Economic Cooperation and Development (OECD) countries that range between 5% and 7%.

The construction sector in Botswana has largely been driven by the Governments investments in infrastructure and mining sector. With regard to the latter, construction activities have been associated with direct development of mines and, indirectly, with infrastructure related to mining such as roads, utilities and residential houses. Growth in the construction industry has therefore been closely linked to and influenced by Government investment in physical infrastructure.

However, according to the Budget Speech of 2007, during 2005/06, the economy has considerably declined to a negative growth rate of -0.8 percent. This has mainly been attributed to low performance of sectors such as agriculture, manufacturing and construction which declined by more than 3 percent and low implementation of development projects resulting in under-spending by P667 million.

[46] Central Statistics Office, CSO (2000).

[47] Central Statistics Office, CSO (1999).

Sustainability in construction is vital both for growth and for improving the quality of housing. Precedent studies indicate that sustainable development is a process that can be initiated in Botswana through institutional programmes. The government has the capacity and structures to lead the sustainable development of infrastructure.

3.6.1 Policy and Legislation

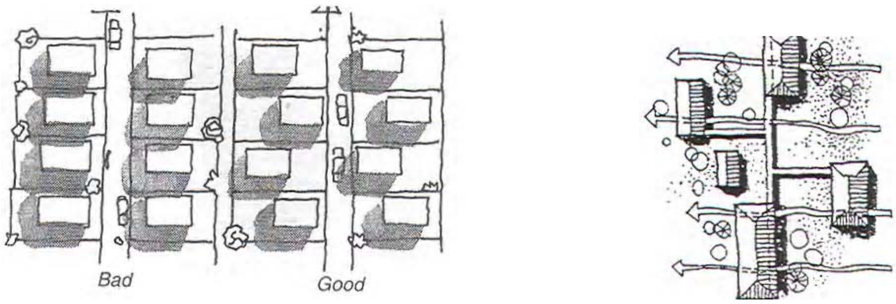
Current policies and legislation do not address sustainable development in construction and housing. Despite global challenges such as global warming, ozone depletion, desertification, acid rain and growing energy (and resource) demand, there is no dedicated policy for integration of sustainable housing practices in Botswana. The building regulations are also lacking in this aspect. Interviewed stakeholders in the housing development sector reported a general lack of resources, research and skills.

However, the process is underway. The country has signed and ratified a number of international protocols that address these global challenges such as the United Nations Framework Convention on Climate Change (UNFCCC). According to the Ministry of Works, Transport and Communications (MWTC) Report of 2001, the objective of this convention is to stabilise greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.[48] Botswana ratified the Convention on the 27th January, 1994.

For example, sustainable planning practice need not cost a lot of money, such as the sustainable neighbourhood strategy of staggered plots that is depicted in figure 21 overleaf.

[48] MWTC Report (2001). 'Botswana Initial National Communication to the United Nations Framework Convention on Climate Change'

FIGURE 21: Staggered layouts for Wind Ventilation



Source: Holm, D. and Viljoen, R. (1996)

According to Holtzman, it is possible with limited resources to design and build affordable, decent, multi-generational, accessible, energy efficient and environmentally friendly low cost houses; build-ability and well designed are not mutually exclusive.[49]

3.6.2 Planning

Gibberd supports the development of sustainable infrastructure for developing countries as a means of addressing key sustainable development objectives for social and economic equity and addressing of environmental aspects for social and economic benefit. He notes that developing countries tend to have indigenous systems that are sustainable in the form of technological, social, cultural, organisational and knowledge systems. These systems can provide valuable models for sustainable development. Gibberd describes the building as having both a physical (the building) and a dynamic entity (having a life cycle) and that in understanding the finite building elements we can understand the workings of the building system.[50]

[49] Holtzman, A. (2003). "build-ability and well designed are not mutually exclusive".

[50] Gibberd, J (2003). The building elements are defined in a simple way that enables them to be broken down into a series of finite elements that cab be used to understand the workings of the system and to develop a sustainable framework.

- The building elements are location, site, size and shape of the building, building envelope, internal space, furniture and fittings, services (such as electricity, water and telephone), materials and components.
- The life cycle of the building is in stages: briefing, design, construction, operation, refurbishment and demolition.

To establish a framework for sustainable and resource efficient low cost housing, it is critical to identify and analyse the modifying factors that exist in the current low cost housing sector. The region, the settlement and the residential neighbourhood are the key modifying factors for housing construction. They can best be resolved through:-

a. Adequate polcy, legislation and regulation
b. Decentralised and integrated planning.
c. Appropriate support structure such as relevant research, strategy, plans and frameworks.
d. Participatory approach.
e. An enabling environment such as sustainable finance and incentive schemes.
f. Capacity building.

3.6.3 Development

As identified above, at a basic level developments or services are driven by the decision-making processes namely Policy, Financial Performance and Governance which tend to influence decisions and integration at three levels; the macro, meso and micro level.

a. The Macro Level

The macro level players are central government, its agencies and other international policy bodies. Their role is to establish both generic and sectoral policies, strategies, regulations and guidance within a set framework for decision making. These may or may not include sustainability and consumption at the meso and micro levels.

The intention is that strategic decisions taken at this level help to create context and incentives for decision makers at meso and micro level to consider integration.

b. The Meso Level

The Meso level consists of trade associations, regulators of standards, planners and implementing agencies, NGOs and municipalities. Their role is to make policies and enforce them at the local level. This level has the ability to influence central government policies and make policies at regional level.

It consists of key movers; through awareness raising and lobbying. This level is can influence change towards integration and good practice in both the public and policy-makers. Hence they can be used to implement change or lobby for change of framework conditions.

c. The Micro Level

The Micro level consists of market based actors like producers, retailers and consumers. Here day to day decisions are made on production and consumption of goods and services within the wider framework set at macro level. These decisions are driven by perceptions of risk, opportunities and need/demand and they are quick and not constrained. Hence awareness and availability of information can influence micro level decisions and is likely to have significant impact.

3.7 INTEGRATED HOUSING

This level of urban planning and architecture approaches housing development with the appreciation at different scales. Policies, strategies and development plans need a collaborative effort to ensure that national and regional scale planning takes into consideration the impact of decisions at local scale.

3.7.1 Resources

Building density of the surrounding area, resource requirements (especially energy and impacts) need to be considered. Gaborone is planned on mixed use city structure with the juxtaposition of commercial, industrial and residential areas. The development of housing needs to take into consideration this factor. Ground surfaces like roads and paving radiate their absorbed heat and large buildings tend to block wind and solar access for the smaller buildings like low cost houses. Buildings are meant to have at least six hours of solar access. According to Holm and Viljoen, some of the leading countries in solar passive design have legislated for protection of full sunshine from 09:00 to 15:00 hours.[51]

[51] Holm, D and Viljoen, R. (1996).

In sustainable housing design, building orientation, form and layout are used to achieve optimum design. Sustainable housing design should be:-

a. Compact and square rather than rectangular.
b. Multi storey rather than single storey to reduce heat loss. There is lees exposure of wall area.
c. The building on the site must face north. If the sites are too small to orientate the house, then the sites themselves must be orientated north.
d. Boundaries of the sites should run as near to the north-south and east west as possible. To achieve this, the roads should run north-south and east-west.
e. The houses should be staggered so that they do not shade each other.
f. Vegetation should be carefully introduced to shield the house and provide shade, yet avoid blocking the sun and prevailing winds.

3.7.2 Design

The key to improved performance of the building (or house) emanates from understanding the thermal system of the building.[52] The building or house in our case, functions as a system which reacts to external factors. Understanding the thermal system of the building leads to the understanding of the building envelope. The main components of the thermal system of the building include:-

a. Internal heat gains from heat generated by occupants, lighting and appliances.
b. External heat gains through building envelope through solar radiation.
c. Ventilation of indoor space with outdoor air results in temperature heat gains or losses.

Understanding of thermal system, leads to design that is in harmony with nature. Such design uses natural elements such as the sun, wind and materials for optimum performance of the building and provision of user comfort. The building envelope is then designed to react to surrounding climatic factors. This approach uses the climate to design to achieve natural cooling and heating, natural lighting and ventilation.

[52] Holm, D and Viljoen, R. (1996).

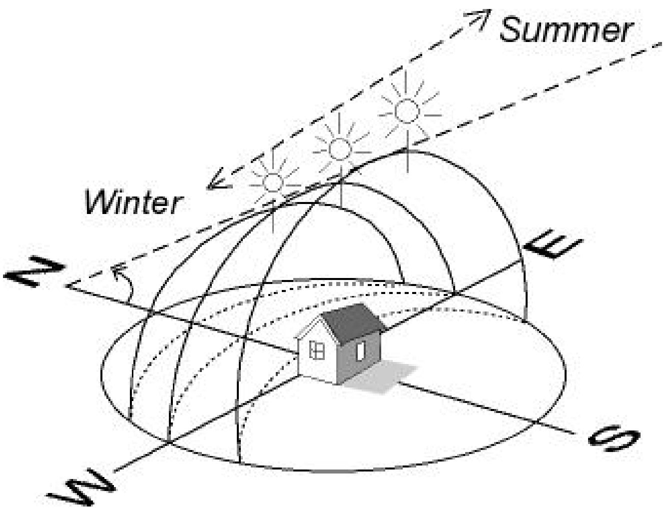
The building envelope separates the indoor and outdoor environment. Hence, consideration for its thermal performance needs to be addressed through:-

i. Materials or combination of materials. There is need to check the physical and thermal properties selected materials in terms of their thermal capacity, reflectance, conductivity, porosity and density.
ii. Orientation of the house and rooms to avoid heat gain or heat loss. Different functions of the house such as services (bathrooms, storerooms etc.) are positioned to act as buffer zones to shield the living and sleeping areas.
iii. Outdoor environments are rationalised in relation to the surrounding built environment, access, hierarchy of spaces, levels of radiation, wind and humidity.
iv. Indoor environments are rationalised in terms of quality of space(s), flexibility, and resource usage including heating and cooling loads.

3.7.3 Key Factors

One of the key factors to designing with the climate is the understanding of the movement of sun. In the southern hemisphere, the sun moves around the building on a path from east to west. It is slightly north in summer and further to the north and lower in the sky in winter, as illustrated in Figure 22 below.

FIGURE 22: Seasonal Movement of the Sun



Source: Ward, S. (2002)

Particular attention has to be paid to the urban environment which has a tremendous effect on the micro climate due to waste, heat, pollutants, reflectivity and rainfall runoff.

Climate and weather depend on geographic location, which means the climate is influenced by the topography of the site. Regional climate data can assist design. It is usually expressed in terms of solar radiation, temperature, humidity and wind pattern.

3.7.4 Solar Radiation

Solar radiation influences the heat gain by buildings and the availability of energy in the case of photovoltaic (PV) and solar water heating systems. Maximum benefit from solar radiation is determined by its intensity and duration and hence the importance of sun movement when designing. The intensity of solar radiation is determined by a number of factors including:-

a. The sun angle, which describes the position of the sun in the sky relative to earth and is used to predict shading patterns caused by obstructing and shading devises on the building.
b. The amount of radiation, which depends on the angle of incidence and the relative solar path. The greater the acute the angle, the less the radiation; the longer the solar path length, the less the radiation.
c. The duration of the solar radiation is determined by the possible solar radiation for a specific region or place. It is further dependent on the topography and the climate of the area.

3.7.5 Temperature, Humidity and Wind

At microclimatic scale, temperature is affected by solar radiation, humidity and winds.

a. Temperature

The higher the solar radiation, the higher temperature; and temperature drops at night due to the absence of solar radiation. Hence the air temperature is affected by surrounding surface materials including their colour and texture. These influence the materials' absorptive and emissive properties. Dark, coarse surfaces absorb more solar radiation than light, smooth surfaces. Hence different parts of the building envelope contribute to the thermal stability of the building envelope. For instance, windows, doors and skylights are one of the major source of heat gain or loss per unit area in a building. In winter and at night, they become the greatest heat loss medium. While, in summer they lead to solar heat gains through radiation.

The amount of solar radiation gained through openings is determined by the type of the glass, the size of the opening, its position and orientation. Different types of glass transmit heat through them in different ways. Single glazing allows more heat penetration in (in summer) or out (in winter) of the building. Strategies such as double glazing, solar controlled glazing and shading of the building reduce heat penetration in summer and heat loss in winter. Shading by the building envelope includes appropriate sizing and location of opening, deep reveals, solar control devices and vegetation.

b. Humidity

Humidity plays a role in regulating temperature. Humidity results in hot regions experiencing lower temperatures while cool regions experience higher temperatures. This principle is used in evaporative cooling design for hot arid regions.

c. Wind

The building envelope is the moderator of the indoor environment. Prevailing winds cause fluctuations in temperature resulting in heat losses or gains to the building. Hence, infiltration has an effect on thermal performance of the building envelope.

However, prevailing winds can be used to advantage to ventilate buildings and improve their thermal comfort in summer, as in the case of the Energy Efficient Residence. Thus understanding the local climate leads to improved design of housing.

3.8 THERMAL PERFORMANCE

A building's thermal performance is determined by a number of factors that are inherent in the design. Different parts of the building envelope contribute in various ways with the roof and glazing being the biggest contributors to temperature swings. Understanding of materials or combination of materials can be used to advantage when designing. This can be of benefit to low cost housing.

3.8.1 Thermal Mass

High mass reduces temperature swings in a building. Thermal mass is a property of building materials that is necessary to achieve thermal comfort relative to the climatic zone. In hot semi-arid regions like Botswana with temperature swings of 15 to 18 degrees, thermal mass is used in summer primarily for its insulative and time lag properties. While in winter it is used for its heat storing capacity. To benefit from thermal mass, the building envelope needs materials with high density and high specific heat for optimum performance.

3.8.2 Insulation

Insulation offers resistance to heat flow and contributes to the reduction of temperature swings in the building. There are two categories of insulation materials; reflective and resistive. Reflective insulation materials have high reflectance, low absorption, and low emittance of heat. They prevent radiated heat gain or loss and are effective only when placed adjacent to an air cavity. An example of a reflective insulation material is shiny foil. Resistive insulation materials are characterised by bulk insulation, have low density, retard heat flow. They prevent air movement. An example of a resistive insulation material is glass-wool.

3.8.3 Ventilation

Ventilation is the fresh supply of air into the building. This can be achieved through manipulation of the prevailing winds on the site. The careful location of the house on the site with respect to prevailing winds enhances the quality of ventilation.

Prevailing winds create characteristic air flow patterns around buildings and their surroundings. The windward side of the building experiences positive pressure while the leeward side experiences negative pressure (suction). Hence, the position of windows and doors needs to be strategic.

a. Windows/doors – are not to be placed parallel to wind direction.
b. Cross ventilation – achieved by placing windows on opposite sides of the room.
c. Larger windows – placed on leeward side on a sloping site.
d. Control wind speed – by using surrounding buildings, vegetation, screens, louvers, canopies and blinds.
e. Types of windows - horizontal pivot windows direct air flow downward; vertical pivot or casement windows catch air or wind from other directions.
f. Air tight building - avoids infiltration.

3.8.4 Day Light

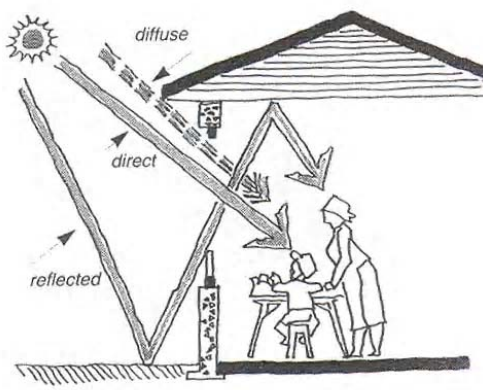
According to Holm, the quality of natural day lighting has the following benefits over artificial lighting:-

a. It gives better colour definition.
b. It has psychological benefits. Artificial lighting tends to give a monotonous environment.

A number of factors influencing daylight distribution and intensity, such as the orientation of openings and space organization, size of openings, materials and their properties and light characteristics of the glazing material.

The disadvantage of day lighting in a building is the introduction of glare. Design of housing needs to consider the ways in which day lighting is introduced into the building. Several ways exist including direct, diffuse or reflected, as shown in figure 23 below.

FIGURE 23: Light Penetrating the House



Source: Holm, D and Viljoen, R. (1996)

Day lighting can be achieved through,

- indirect day lighting,
- less transparent glass, and
- solar control devices.

Some of the strategies have little or no cost and can be of benefit to Botswana's low cost housing which relies mainly on natural lighting.

3.9 ACTIVE SYSTEMS

Sustainable, energy-efficient housing design calls for optimum design of the building envelope. However, in some climates such as Botswana, where sometimes extremes of temperature are experienced, there may still be a need for additional heating or cooling to achieve thermal comfort. This may be achieved through passive solar heating or cooling systems. The Climate and house design will determine the applicability of passive cooling systems.[53] The systems include ventilative cooling, radiant cooling, evaporative cooling or soil cooling. Some have been tried in Botswana in larger buildings like offices.

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[53] Givoni, B. (2004).

The study considers these systems to be unaffordable for the current low cost housing of Botswana. However, these may be affordable through higher density housing for institutional projects.

Passive systems require additional initial costs but have long term benefits that include reduced use of fossil fuels, reduced energy consumption and reduced demand on the national electricity grid.

3.10 APPROPRIATE MATERIALS

Materials are one of the modifying factors of the building envelope. Sustainable and resource efficiency of low cost housing can be enhanced by design that is informed by the understanding of material properties and characteristics.

Materials used for the building envelope (roof, walls, ceiling and floor) are very important for the thermal performance of the building and hence the following properties of materials must be taken into consideration;

3.10.1 Quality of Materials

The quality of the materials must be investigated for their conductive and insulative properties and to use the right combination of materials, as discussed in section 3.8 above. Energy Content of Materials

3.10.2 Environmental component

Sustainable housing requires environmental sustainability in construction, upkeep and recycling. This can be achieved by appropriate selection of materials. Considering:-

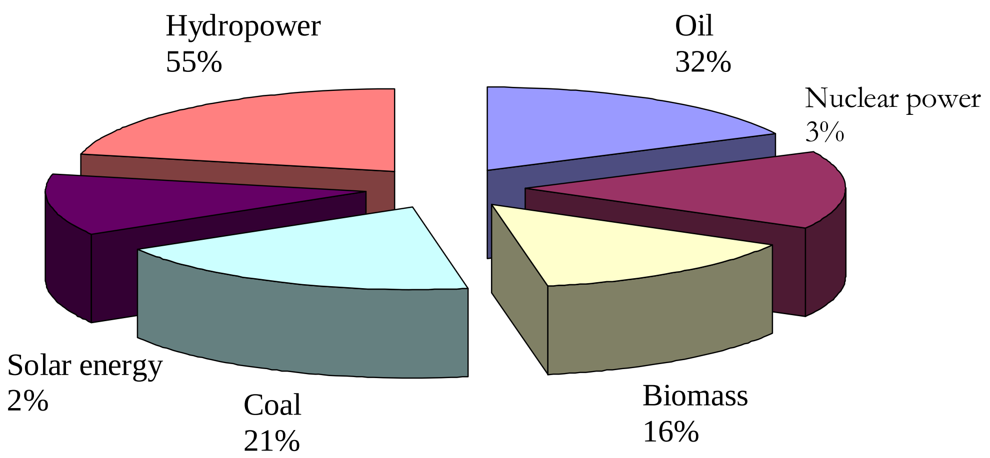
a. Energy content of materials (the amount of energy used in their production).
b. Embodied energy and transport energy.
c. Environmental relief of the material or product.
d. Environmental compatibility (using the material's annual carbon dioxide volume production versus another material or technology that it replaces (substitutes).

Some international standards are available which can be used for benchmark and or adaptation.

3.11 APPROPRIATE ENERGY

Energy is one of the essential support systems for housing. However, there is a world-wide concern regarding energy as some of forms of energy have side effects such as pollution, damage to the health, negative impact on the environment and increased demand on fossil fuels. This is compounded by equally non-sustainable energy consumption patterns. Figure 24 below shows the extent of global dependency on fossil fuels.

FIGURE 24: Global Energy Consumption



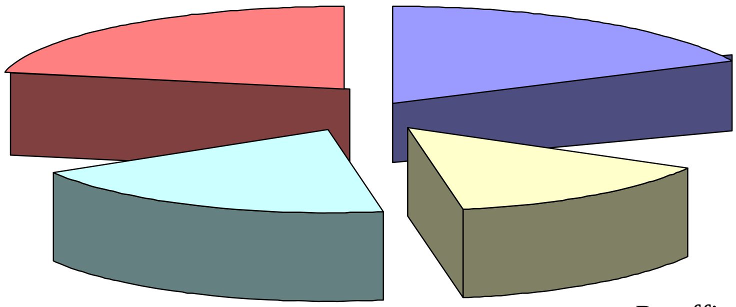
Source: Ward, S. (2002)

The Botswana Power Corporation (BPC) growth projections show increased targets for electrification of SHAA areas in Gaborone and Francistown in addition to the Village Electrification Programme.[54] In 2005, the BPC recorded 13,585 areas connections (higher than target of 13,080 connections). Ninety percent of the connections were in the domestic category.

[54] Botswana Power Corporation Annual Report (2004).

Limited access to electrical energy is one of the major challenges facing Botswana today as seventy percent of the country's electricity is imported from surrounding countries i.e. South Africa and Namibia. In view of the impeding post independence electrification programmes in South Africa, there is a threat of availability of electricity to Botswana by 2007. Figure 25 illustrates the increased reliance on electrical energy in Botswana.

FIGURE 25: National Energy Supply



Source: Department of Energy Project Guide (2003)

The dependency is expected to increase. Hence, proper planning and rationalisation of energy is vital for all sectors including the housing sector. Reduction of domestic electricity usage would be a significant contribution to the country's consumption and to the eminent impact on peak demand by 2007.

According to Shove and Warde, more attention needs to be paid to the dynamics of demand for electricity or for inconspicuous energy consuming services as such issues are perceived to be of more concern in the development of socio-technical systems.[55] He states that two important aspects need to be considered; building thermal performance and domestic

[55] Shove, E. and Warde, A. (2001).

appliances as these have the potential to reduced energy consumption. Sustainable construction practice is imperative for Botswana and the low cost housing sector.

Considerations for alternative energy sources and resource conservation need to be become part of building design. The United Kingdom, BREEAM, was devised by British Research Establishment (BRE) as a method to certify buildings for environmental responsiveness. This approach empowers the building sector to make the informed energy choices and encourages voluntary self monitoring.[56]

3.11.1 The Role of Alternative Energy

Alternative energy offers decentralised local energy solutions that are based on renewable forms of energy. Developed countries including Germany, Japan, Denmark, United Kingdom and the United States are turning to alternative sources of energy due to the realisation of the increasing disparity between the supply and the demand in energy. Efforts are supported by relevant policies that were developed over time.

India and China have also started to take a keen interest in the development and use of renewable energies. According to Shell's published figures of 1994, the world's primary energy target set for 2050 is that 50 to 100% of our energy will come from renewable energy.[57]

Botswana is blessed with abundant sun for most of the year and has a huge potential for the harnessing solar energy. However, efforts have been on a small scale, with solar water heaters being prevalent. In Botswana, renewable energy is perceived to be costly with long pay-back period and difficult to maintain. Lack of relevant strategies inhibits the uptake of the technologies.

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[56] http://www.bre.uk.com/jul06.

[57] http://www.shellfigures/mar07.

There is need for more research into appropriate alternative energy sources for Botswana and some of the known ways for harnessing solar energy were identified by the literature review of the study and presented as appendix 6.

3.11.2 Indoor Comfort

The ultimate goal of achieving sustainable, energy efficient housing is the improvement of the quality of indoor spaces. Good thermal performance of a building is achieved through investigations on the relation between the human body and thermal comfort. Thermal comfort zones need to be defined to indicate a range where most people will feel neither too hot nor too cold. The comfort zone is usually characterized by a number of parameters including the temperature range, humidity, ventilation rate, metabolic rate and the amount of clothing.

Thermal comfort can be determined in a number of ways. Traditionally, thermal comfort is understood based on a mathematical model of the heat exchange between the human being and the thermal environment. However, according to the heat exchange model used in mechanical engineering studies including ASHRAE[58], it has been found to have some practical limitations as some parameters cannot be predicted. Clothing, metabolic rate (depending on type of activities), air movement (people will open/not open windows) and tolerance level of different people and societies result in these limitations.

Field study research is an alternative way of discovering the room temperature which a group of people find comfortable. People going about in their normal activities are questioned about their thermal comfort and the thermal environment is measured. No attempt is made to alter their behaviour/environment. The result is a similar reaction to their real-life context.

The latter method is more applicable to housing than the heat exchange method, and is immediately suitable to minimizing the use of energy for heating and cooling buildings and is useful in design.

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[58] http://www.en.wikipedia.org/wiki/ASHRAE/aug07.

3.12 CHALLENGES

Some of the identified challenges towards sustainability, resource efficiency and thermal comfort in low cost housing of Botswana and most developing countries are discussed in this section.

3.12.1 Affordability

Literature review has demonstrated the importance of sustainability and energy efficiency in low cost housing and the associated socio-economic and environmental benefits. However, poor people cannot afford to invest upfront and hence there is a need for cost benefit studies. A number of cost benefit studies have been conducted throughout the world in order to check the viability of programmes including the cost benefit analysis study by the Energy and Development Research Centre at the University of Cape Town in South Africa. The study was found to be relevant for Botswana as both countries are in the southern hemisphere and are both developing countries.

The study analysed the costs and benefits of different energy efficiency approaches and technologies for typical low cost houses.[59] Measures with low cost but high benefit were identified to be:-

a. Ceilings.
b. Roof and wall insulation.
c. Window size.
d. Partitions.
e. Shared walls in row housing.

The benefits include reduced household expenditure, improved health and the potential for employment creation. It was established that appropriate housing development is a result of adequate support structures and a major player is housing finance.

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[59] Ward, S. (2002). Lifecycle costing used to get the sense of what the real costs are for the different uses in the home. Life cycle cost = Initial E cost + initial appliance cost + regular energy cost + appliance maintenance cost + other costs

3.12.2 Housing Finance

Low cost housing forms 60% of the residential sector of Botswana. The majority of this sector cannot afford to build quality housing at current rates and using existing housing structures. Financing of sustainability and energy efficiency is difficult to achieve through recurrent budgets and calls for creative funding solutions.[60] Some of the already available solutions such as "Green financing" and the Clean Development Mechanism are not accessible to Botswana. Finance strategies and solutions need to adapt to already existing structures like SHHA and power charging systems.

The Botswana Government is largest employer and the biggest player in the construction sector and is better - placed to kick-start the integration of sustainability and resource efficiency and implementation of interventions to encourage good practice while reducing embodied energy and negative impact on the environment.

3.12.3 Implementation

Change in housing development practice requires a paradigm shift in the execution of programmes and projects. There needs to be development and implementation systems suitable for the context of Botswana. All involved in the housing development process need to work together. There are proposals for policy, standards, building regulations, planning, design, and installations interventions.[61]

Established alternative implementation strategies need to include retrofitting of already existing residential buildings and potential for retrofitting is discussed in the next section.

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[60] Sustainable Housing Project Stakeholder Report. (2006).

[61] Tumisang, H. (2005). Proposed Planning and Design Interventions include the following, 1. A major review of present planning system to incorporate energy efficiency, 2. An integrated approach to planning and design. 3. Review of the tendering and evaluation process to include energy efficiency. 4. Establishment of guidelines for energy efficiency in building designs

3.12.4 Retrofitting

It is easier to influence change in new housing developments since the costs seem to be quite comparable with conventional house construction. However, some key building elements were identified for retrofitting of existing housing, for the improvement of thermal performance.

The challenge was to what extent can housing be made more energy efficient in response to higher energy demands and at what cost compared to savings in energy? This is addressed by:-

a. A survey of physical changes (energy retrofits) that need to be made to various housing types in order to improve their energy efficiency.
b. Technical potential for improving the energy efficiency and thermal comfort of the residential building through energy management are also need to be investigated.

The idea would be to identify on average, retrofits to existing buildings of most types that are practical, feasible and have low capital cost compared to saving such as the orientation of the house, the size and location of openings (windows and doors), correct treatment of the façade, material selection, and the type of roof.

Specific energy retrofitting to include the choice of energy and appliances such as changing to domestic solar hot water systems and energy efficient light fittings such as compact fluorescent light (CFL) bulbs.

A retrofitting example is the United States of America Federal Urban Housing Rehabilitation Programme which was undertaken by the Department of Energy. Retrofits were found to offer a good investment on return, over time. Evaluation cited evidence of the program having stimulated retrofit even among private buildings. [62] This example suggests economic viability for energy or retrofit oriented market as the programmes produced positive side effects such as the creation of a new community of energy auditors. Table 3 overleaf shows retrofitting results from one of the schemes OTA programs.

[62] OTA Reports (1998).

TABLE 3: Retrofit Options and Potential Savings

Retrofit	Category	Retrofit cost ($)	Total energy savings (million Btu)	Capital cost per annual Btu saved ($)
Wall insulation	envelope	4700	40	High (114)
Change in type of windows	envelope	450	20	Moderate (21)
Window insulation	envelope	420	8	High (53)
Mechanical changes-dampers, controls, fans	mechanical	150	6	Moderate (25)
Hot water storage	Hot water	30	7	Low (4)
Insulate ducts	mechanical	810	15	High (54)

Source: OTA Reports. (1998)

The study notes that the retrofit results were taken from a different context. However, similar results for intervention were observed in a Cape Town (South Africa) research. Results demonstrate that the public sector has a huge role to play in the implementation of interventions. This is important to note in Botswana where the government is the main client for projects and institutional housing. For positive impact, research in housing development should target institutional housing.

3.12.5 Benefits

Sustainability and resource efficiency in low cost housing has numerous benefits that relate to the individual, the nation and the surrounding environment.

a. Individual Benefits

Benefits include cost saving, due to reduced need for heating or cooling, improved indoor quality, health and comfort; and improved natural lighting inside the house for daily chores.

b. National Benefits

There are envisaged savings for the local authority's services and maintenance costs and less demand for the dwindling electricity. Others include less demand for health and welfare facilities and or programmes. Ecological smart buildings offer a favourable ratio of rent to operational costs. Most financial investors are now concerned with ethics & ecology as much as financial returns. The life cycle of the project is scrutinised for future energy impact in the environment

c. Environmental Benefits

There will be fewer pollutants released to the atmosphere and less demand on non-renewable energy resources.

Chapter 4

SITUATIONAL ANALYSIS

4.0 INTRODUCTION

Situational analysis was geared towards assessing the current housing situation in Gaborone in order to inform the intended framework on sustainable, energy efficient housing for Botswana. The analysis is achieved through survey research which involves data collection and analysis for the purpose of determining the state of low cost housing and building practice.

Preparation for data collection included identification of data sampling methods, assessment tools and procedures.

4.1 DATACOLLECTION

The research was limited to Gaborone due to resource constraints. A residential area of Gaborone, Gaborone West (G. West) Phase 1 was selected and a stratified sample of the housing population of G.West Phase 1 selected, in keeping with the typical strata of housing types found in Gaborone (SHHA, BHC, Institutional and private housing). Sampling methods, tools and procedures were adopted depending on the data to be collected and the purpose.

For observation studies, a comparative study of one example from each housing type was investigated in terms of planning aspects, design, materials, energy and resource usage.
Survey research used probability sampling to obtain a representative population frame of the housing population of Gaborone.

4.1.1 Sampling for Observation Studies

Four categories of housing types were identified in the urban low cost residential sector of Botswana, namely SHHA, BHC, Institutional, and Private. The BOTEC low cost experimental house was selected for benchmarking purposes as it is one of the few best practice demonstration houses in the country. One example was selected from each housing type and analysed with respect to the degree of sustainability (including planning, design, social, economic and environmental aspects) and resource efficiency (including conservation, re-use and recycling).

4.1.2 Sampling for User Questionnaire

The user questionnaire was aimed at acquiring specific user information that the study needs in order to address particular aspects of the research problem. Its structure had to take into consideration the target population and its background. Its application required adequate introduction of the researcher, the problem of study, the purpose of exercise and permission to interview the user. It was designed with simple short questions requiring short answers preferably of one or two words. The length of questionnaire also was timed not to take too long to avoid alienating the user. The user was advised that the findings of the study could be availed to the user on request.

The method of application (face to face interview) of the questionnaires was preferred as it gives the ability to gain first hand information about the user and the product. According to surveysystems.com, the user tends to be more tolerant to face to face interviewing, especially if it is prearranged.[63]

[63] http://www.surveysystem.com/april 06. Personal interviews can take place anywhere, enabling access to the target population. Long interviews can be tolerated especially if conducted at home. However, personal interviews usually cost more and are time consuming.

The user questionnaire application was executed in stages as follows:-

a. Pre-testing the Questionnaire (Pilot-study)

A pre-test questionnaire was prepared and administered to a couple of BOTEC employees who reside at the experimental staff houses. The purpose of pre-testing the questionnaire was to get an opportunity to test the questionnaire on a few participants prior to the main interview. The pilot study revealed unanticipated problems with question wording and instructions, leading to improved quality of results.

A few of the pre-test questions were found to be open-ended and some confusing. The findings of the pilot study were not used as data for this study as they contained some errors. However, the errors were used to improve the final questionnaire and the user interviews. The final format of the questionnaire is presented in annexure 2, for ease of reference.

b. Stratified Random Sampling

Due to limited resource constraints it was not possible to survey the whole housing population of G. West Phase 1. The study used a representative sample selected using the random sampling method. Random sampling means choosing a sample in such a way that each member of the population has an equal chance of being selected.[64] The data from such a sample is assumed to be representative of the entire population of study. A stratified (proportional) random sampling was conducted to ensure that all strata of the population in line with proportional representation in the sampling frame are sampled.

Stratified random sampling divides the population into homogenous subgroups and a simple random sample of each subgroup is taken.[65] The population is divided into non-overlapping groups (strata) N1, N2, N3… and Ni.

N = number of cases in the sampling frame (N=N1+N2+N3+…+Ni)

n = number of cases in the sample

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[64] Leedy, P. D. and Ormrod, J. E. (2001).

[65] http://www.socialresearchmethods.net/april 06. Stratified random sampling also called the proportional/quota random sampling is usually preferred over simple random sampling. First it assures that not only the entire population is represented but also key subgroups of the population.

f = n/N = the sampling fraction

The study took a sample frame of 38 houses of mixed variety from the identified categories SHHA, BHC, Institutional and BOTEC, as identified in section 4.1.1. From this the researcher chose a random sample of houses from each house type. The ratio of house types was found to be 60:20:10:5 and hence the numbers of houses sampled matched this ratio.

4.1.3 Sampling for Stakeholder Interviews

The purpose of stakeholder interviews was to gather technical information, engage with stakeholders in residential sector including architects, engineers, developers, environmentalists, and planers on housing construction practice, legislation, resources, appliances and suppliers relative to sustainability and efficiency of housing development. The following multi-discipline stakeholder groups were identified in the Botswana.

a. Policy
    i. Department of Housing, DOH.
    ii. Department of Energy, DOE.
    iii. Department of Town and Regional Planning, DTRP.
    iv. Department of Environmental Affairs, DEA.

b. Regulation and Implementation
    i. Department of Buildings and Engineering Services (DBES).
    ii. Botswana Housing Corporation (BHC).
    iii. The Self Help Housing Agency (SHHA).
    iv. Gaborone City Council (GCC).
    v. Botswana Bureau of Standards (BOBS).

c. Public and Private Stakeholders including architects, engineers, developers and material/equipment suppliers.

The idea was to gain insight into current housing construction practice, raise awareness, share information and build capacity.

4.1.4 Questionnaire Design

The design of the stakeholder interview questionnaire covered similar parameters as the user questionnaire in section 4.1.3 above and a copy is included in annexure 3. However, the format differed as follows:-

a. The stakeholder interview questionnaire was designed to accommodate the multi disciplines.
b. The majority of questions were technical and allowed for discussion.
c. The stakeholder had access to the questionnaire prior to the interview.

4.1.5 Application

Letters requesting an interview with the stakeholder were posted followed by an appointment arranged by phone at least two weeks prior to the interview date. Once the interview was agreed the questionnaire was dropped – off by a copy of letter from the University of Pretoria confirming the author‘s registration with the university, a letter from the author’s employer and a formal cover letter from the author seeking permission to interview. The latter explaining the nature of the study and its purpose. A day before the interview, a phone call was arranged to confirm the appointment. The interview structure is shown below.

a. Introduction of self.
b. Brief research background.
c. Purpose of the interview and why the stakeholder was selected.
d. Conduct the interview, guided by the questionnaire format.
e. Allowed some comments and questions at the end of the questionnaire. Questions were discussed and in some cases the interviewee was informed that the answers were expected to come from the survey.
f. Gratitude was extended for allowing the interview and assurance given that the data collected would only be used for this study and that the data would be made available to them, if needed.

A number of appointments had to re-schedule to meet with the interviewee's schedules. About 90% of the targeted stakeholders were interviewed. The rest of the stakeholders were not available due to work commitments.

4.2 ASSESSMENT TOOLS

According to Sustainable Housing in Europe (SHE), the objective for sustainable diagnosis and design is to prepare and introduce in the design phase, detailed actions and prescriptions regarding architectural, engineering and resource (energy, waste and water) aspects, starting from site analysis and diagnosis, and to set up a comprehensive approach both on a neighbourhood and building scale, aiming to reduce building environmental impact, to reduce water and energy consumption and promote the use of natural resources.[66] The study sought to benchmark against an assessment tool that embodies this objective. The Sustainable Building Assessment Tool (SBAT), was found to be an appropriate benchmarking tool for this study as it was developed in South Africa which is a developing country like Botswana and situated in the same region.[67] The tool allows for continuous assessment of the building design process by checking the sustainability of the design. From the concept stage, the professional is able to make decisions on space, the building envelope, materials, services etc.

The study used the research findings and benchmarking systems to develop an appropriate framework for sustainable, energy efficiency design for low cost housing for Botswana.

[66] www.she.coop/english/pres/jun06.

[67] Gibberd, J. (2003).

4.3 OBSERVATION STUDIES

The reason for observation studies is for thorough investigation of the different types of residential buildings.

4.3.1 SHHA Low cost Housing

This house is on a standard subsidized 450 metre-squared plot located in a designated SHHA area which has plots that are serviced up to street level, providing basic amenities such as gravel road, water and electricity.

- Plot 14931, G. West, Phase 1, Gaborone.
- Type: Private owned (incremental house)
- Architect: Owner
- Builder: Owner
- Owner: Mr. G. Molefe stays with wife, two children, cousin and one room rented
- Completion date: 1990
- No. of units 1 (x3)
- Unit cost: P10, 000 per room
- Energy cost: P75.00 per monthly, equal to 8.3% of income
- Average monthly salary: P900.00

Typical of SHHA housing, this is a single dwelling on a single plot. It is small and part of many plots that are crammed together to accommodate the population of the low income sector. Although the SHHA office has standard house plans, this incremental house was designed by the owner and builder similar to the majority of SHHA housing. It started as one room and an additional two rooms were added over a period of five years and one of the additional rooms has been rented out for extra income. A case study analysis is carried out below.

Urban Planning and Design:-

a. Overall urban plan of Gaborone West Phase 1 is a mixed housing development. (social mix) area bordered by a small shopping complex and entertainment amenities. It is 15 kilometres from the city centre and industrial area. Reduces transport to shopping but not to employment.

b. The area is serviced by tarred arterial roads and un-tarred internal roads, no pedestrian or bicycle routes.
c. Large blocks of plots with narrow passages (access routes) of about 2 metres. The passages are often neglected and are not paved; have potential to be used by robbers.
d. Plot orientation not sustainable, planning focus is to get as many plots as possible, while reducing servicing costs.
e. Low to medium density, poor sustainability high cost servicing of single plots.
f. Poor integration of development with surrounding area both physically and socially.
g. No community participation in planning. There have been suggestions of Environmental Impact Assessments (EIA) to be enforced in the future but current legislation does not force housing developments to engage EIA. DTRP claim that they conduct EIA at regional planning level when demarcating land for residential /commercial/industrial.

Sustainability of Design, Technology and Materials:-

a. Poor plot orientation in relation of the surroundings.
b. House orientation has poor layout and location of openings, encourages heat gain into the house.
c. Walling material commonly used is the 6 inch concrete block. It offers good thermal mass but has no added insulation or cavity.
d. Floor - 150 mm concrete slab with 20 mm cement screed. The floors have good thermal mass but lack damp proof membrane.
e. Mono-pitch corrugated iron sheet roof, without insulation. The roof has proved to be the main source of heat gain in summer and heat loss in winter. Small roof overhang has little or no benefit to the building envelope.
f. Air bricks over openings good for ventilation
g. Large south facing windows encourage solar radiation heat gain; need to reduce window size, change location or introduce solar shading devices

3. Energy and Innovative Application of Alternative Energy:-

Electrification is done on individual bases. The service is provided to street level and individuals need to apply for connection at an average cost of P7, 000. The BPC system allows for a deposit and payment of the balance over a period of 10 years. This plot has not been electrified due to shortage of funds. In fact, few houses in the area are connected and those who are connected use electricity mainly for lighting and have few electrical appliances. The majority of the SHHA dwellings adopt mix use energy sources that are used for basic functions like cooking, lighting and winter water heating. Some of the mix energy uses are compiled in the table below.

Table 4: Types of Energy sources used

Energy use	**Energy source**
Cooking	Gas, paraffin
Water heating (winter)	Open fire (hearth)
Lighting	Paraffin, candle
Space heating/cooling	none

4.3.2 Council Low cost Housing

- Plot 14988, G. West Phase 1, Gaborone.
- Type: Tenement
- Architect: misplaced information
- Builder: misplaced information
- Owner: Ms. O. Ntaile
- Completion date: 1989
- No. of units:1 (x2), semi detached housing
- Unit cost: P105, 000.00 per unit
- Energy cost: P220.00 per monthly
- Average monthly salary: P3, 800

Urban Planning and Design:-

a. Similar to SHHA plot above, the planning mixed housing development (social mix) area bordered by a small shopping complex and entertainment amenities. No transport costs to shopping and employment as the SHHA office is nearby. It is 18 kilometres from the city centre and industrial area.

b. Plot orientation – not sustainable, focus is to get as many plots as possible, while reducing servicing costs.

c. Medium density housing – achieves better sustainability in construction and servicing costs.
d. Better social development as a neighbourhood concept, however no plan for play areas and external seating areas.
e. No community participation in planning.

Sustainability of Design, Technology and Materials:-

a. Air bricks over windows encourage some cross ventilation.
b. Semi detached houses reduce exposed surfaces of house(s) to the elements (sun, wind); building envelope tends to be thermally stable.
c. Shared walls between houses reduced construction costs.
d. Thermal mass for concrete block walls and concrete floor slab
e. Temperature variations due heat losses and gains due to IBR roofing sheets and no insulation.
f. Small roof overhang has little or no benefit to the building envelope.
g. Heat gains due to large south facing windows.
h. Natural ventilation for air bricks over openings and windows in every room.

Energy and Innovative Application of Alternative Energy:-

a. Plot and house orientation not considered to optimize the buildings thermal performance.
b. The majority of materials are imported form South Africa, thus have a high embodied energy.
c. Mix use of energy sources for various functions:-
    - Electricity is used for lighting, water heating, appliances
    - LPG gas is used for cooking
d. Exposed galvanized plumbing pipes for hot water conduits.

Barriers:

a. Lack of sustainable housing policy and guidelines.
b. Slow introduction and uptake of sustainable interventions (including LFC light bulbs and insulated ceilings).
c. Poor maintenance and resource management programmes.

4.3.3 BHC Low cost Housing

- Plot 15049, G. West, Phase 1, Gaborone.
- Type: Tenement
- Architect: BHC Consultancy Office
- Builder: China State
- Owner: Mrs. R. Moipolai
- Completion date: 1993
- No. of units single
- Unit cost: P120, 000.00 per unit
- Energy cost: P220.00 per monthly, which is 4.5% of income
- Average monthly salary: P4, 800

Urban Planning and Design:-

a. Similar to SHHA plot above, the planning mixed housing development (social mix) area bordered by a small shopping complex and entertainment amenities. It is 23 kilometres from the city centre and industrial area and 30 km from work. No transport costs to shopping only.

b. Plot orientation – not sustainable, focus is to get as many plots as possible, while reducing servicing costs.

c. Low density housing – not sustainable, reduces land, high servicing and building maintenance costs for the developer (BHC). BHC has a couple of flats in the area but they are for middle to high income earners.

d. Poor social development of housing; provides basic shelter without consideration for individuality, adaptability, place making, such as play areas, communal spaces and vegetation.

e. Poor consultation and community participation project implementation.

Sustainability of Design, Technology and Materials:-

a. Thermal mass due to double leaf concrete stock brick walls and concrete floor slab.

b. Temperature variations due to heat losses or gains due to gable IBR roofing which has only ceiling but no insulation.

c. Heat gains from the south and west façade due small roof overhang and large windows.
d. Natural ventilation provided by airbricks over openings and cross ventilation from windows. No windows to take advantage of prevailing winds from the north east.

Energy and innovative application of alternative energy:-

a. No considerations for orientation to maximize energy efficiency for plot or house.
b. The majority of materials used are imported from South Africa resulting in high embodied energy.
c. Mix energy sources are used for various functions including electricity for lighting, and appliances and LPG gas for cooking. There is no provision for water heating and space heating or cooling.
d. Exposed galvanized iron plumbing pipes.

Barriers to sustainability and resource efficiency are due to uninformed legislation, regulation and maintenance systems.

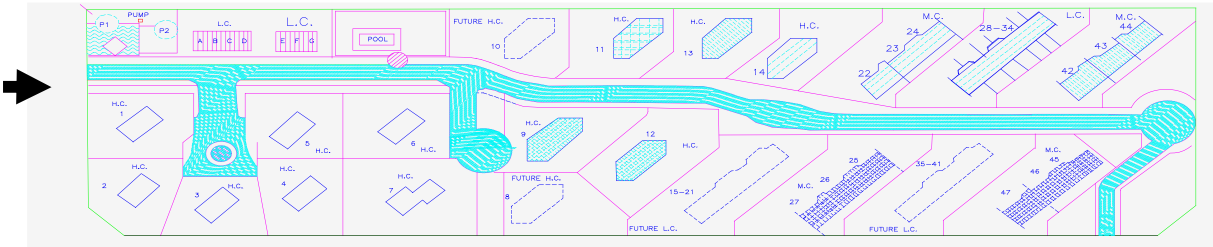
4.3.4 BOTEC Low cost Housing

This building was selected as an example of good practice for benchmarking purposes. Fourteen of the units in the BOTEC plot are low cost and the remainder a mixture of medium and high cost.

- Plot: 14949, G. West Phase 1, Gaborone
- Type: Institutional
- No. of units 1 (x4), semi detached houses
- Unit cost: P45, 000.00 per unit
- Architect: Tswana Design
- Builder: Marapo construction
- Completion date: 1992
- Owner: Ms. T. Keipidile (tenant)
- Energy cost: P236.00 per monthly, which is 4% of income
- Average monthly salary: P5, 800

The low cost unit consists of four attached dwelling units, on a single plot. Each unit has an area 48 square metres and comprises of a bedroom combined with a lounge, a kitchen and shower combined with toilet. The two-and-half hectares residential plot is a narrow site that is surrounded by SHHA and BHC housing developments as shown in figure 26 below.

FIGURE 26: Site plan



Source: BOTEC Housing Report (1992)

Urban Planning and design:-

a. The plot and building orientation support passive solar design with the majority having a skewed north-east orientation and buildings have rectangular shape with short east and west façade to limit exposure to the sun.
b. BOTEC staff is a “compound” housing development with a variety of spaces from private, semi-public (shared spaces) and public spaces. The layout is on a long communal driveway for vehicular access that serves also as a recreational space for cycling and children’s playground.
c. The development is a medium density project made up of mainly terrace housing and a few individual houses.
d. The design is adaptable with each unit having small enclosure on rear for clothes drying that can be changed to into an additional room.
e. Innovation in materials and construction techniques were adopted such as the sagex building system which is a fast erect system that requires less labour and has good thermal mass. BOTEC used four labourers to erect 14 units in two weeks.

Sustainability of Design, Technology and Materials:-

a. Thermal mass also from the concrete slab and thermal mass provided by the 115 mm Sagex (styrene panel) wall construction with 15 mm plaster and paint. The technology has good thermal properties and U-value of 39 W/m2/H/deg C.

b. Good thermal properties from the sagex roof profile, with insulated imported ceiling having U-value of 0.40 W/m2/H/deg C.
c. Deep roof overhang, vegetation and cantilever walls on the south façade provide shade and prevent heat gains in summer.
d. Natural ventilation through cross ventilation from windows. Most openings are located on north façade, to avoid heat gains into the houses; while clerestory windows on the north wall facing into the living room and passage provide "stack effect" or night-time ventilation. Mosquito nets provided for all windows to encourage opening of windows at night.
e. Low flush imported toilets and storm water harvesting for the whole site and stored in underground water tanks; prevents site flooding and water is reused for gardens.

Energy and Innovative Application of Alternative Energy:-

a. Solar water heating is used. It is a renewable form of energy that is used instead of electricity.
b. Mix use energy sources for other functions, including electricity for lighting and appliances; LPG gas for cooking.
c. Subsidised CFL external lights for security reasons and non- subsidised CFL light bulbs for internal.
d. Exposed galvanized iron pipes for plumbing and electricity reticulation.
e. High embodied energy is observed due to imported materials including aluminum window frames from South Africa and Zimbabwe, low-flush toilet cisterns from Sweden, imported ceiling and profile roofing material from South Africa and Zimbabwe.

4.3.5 Summary

Planning and design

The following are the observed challenges that are inherent in Botswana's current housing situation:-

i. Housing neighbourhood/settlement

Residential plots were found to be generally well conceived from the concept of neighbourhood communities that avoids population segregation. Hence, low cost housing is located adjacent to medium and high cost developments. However, the neighbourhood concept has some limitations that were identified by the study and are noted below.

- It lacks hierarchy of spaces and amenities to support living conditions. These are elements that existed in the traditional settlement such as the kgotla and the lolwapa which offered a variety of spaces that were public and semi-private.
- It is impacted on by arterial roads and services.

ii. Density

The low cost housing densities are generally low thus impacting on land and housing availability and accessibility.

iii. Types of Buildings

The majority of low cost housing is designed by individuals, SHHA and BHC. The tendency is to build incrementally one room at a time. However there is no overall plan for future development. The housing loses quality of spaces such as well thought out shaded external seating spaces to support outdoor living.

iv. Building performance

Low cost housing generally performs poorly and does not consider the climate of Botswana or the region. Poor performance materials with high embodied energy are standard practice, with the use of local materials generally limited to rural areas where it is also becoming extinct.

v. Consideration for Sustainability and Resource efficiency

The building life is not considered in the design, choosing of materials and type of construction. Hence, the building and the resources have little or no consideration for the quality of life and the surrounding environment.

vi. Barriers to Sustainability and Resource efficiency

The following were the observed barriers to sustainability and resource efficiency in current housing:-

- Slow policy and legislation implementation.
- Un-integrated regulations and standards.
- Lack of awareness and limited professional capacity.

4.4 DATA COLLECTION

The collected data was classified into different categories inline with parameters set for the research and for ease of analysis.

4.4.1 Pilot study

1. The pilot study was conducted through a draft questionnaire (appendix 2). The collected data was compiled in Table 5 below.

Table 5: Data from Pilot Survey

	Type	**Source**	**Affordability**	**Conservation**
Planning	Conventional	Colonial	Low to medium	Average
Design	Conventional	Colonial, South Africa	Expensive	High embodied energy Poor quality of design
Material	Mostly conventional	Colonial, South Africa	Medium	High embodied energy Poor quality of design
Energy	Mixed energy sources: paraffin fuelwood, LPG gas, electricity	Local and South Africa, Namibia	Expensive	Depends highly on external supply; high embodied energy, unsustainable, non-renewable

2. Analysis

The received data from the pilot survey revealed some limitations as the questionnaire mixed a number of issues and did not fully address the research objectives.

The questionnaire was then reviewed to cover (appendix 2 and 3) and used to conduct the actual survey.

4.4.2 Urban planning and Design

Data collection was conducted through a questionnaire devised in the form of a checklist. Collected data from the survey was compiled and presented in various forms to address the research problem including table 4 overleaf.

TABLE 6: Data on Current Urban Housing

1. Urban Planning	SHHA	Institutional	BHC	BOTEC
Plot orientation	None sustainable. Only considers density and services	None sustainable. Only considers density and services	None sustainable. Only considers density and services	None sustainable. Only considers density and services
Settlement layout	Neighbourhood concept but lacks place-making and amenities	Neighbourhood concept but lacks place-making and amenities	Neighbourhood concept but lacks place-making and amenities	Neighbourhood concept but lacks place-making and amenities
Shopping areas	Well considered, near the residential area.	Well considered, near the residential area	Well considered, near the residential area	Well considered, near the residential area.
Amenities	None	None	None	None, just area demarcation for recreational space.
Services	Water tap, no electricity, no toilet, no sewerage.	All basic services available	All basic services available	All basic services available
Transport	Planned for, majority dirt - roads	Well considered	Well considered	Well considered
Landmarks	None	None	None	None
Orientation	None sustainable	None sustainable	None sustainable	Sustainable
Landscape	No consideration	No consideration	No consideration	Sustainable, drought resistant plants and deciduous plants for shading the buildings
Prevailing winds	No consideration	No consideration	No consideration	Natural ventilation – cross ventilation and stack effect

TABLE 6: continued

2. House form	SHHA	Institutional	BHC	Private
Surroundings	No consideration	No consideration	No consideration	Consideration for surroundings within

				the BOTEC compound. However, SHHA pit latrines too close (smells and cockroaches)
Building envelope	None sustainable	None sustainable	Generally none sustainable.	Sustainable
Design Flexibility	Incremental plan	None	None	None
Design affordability	The cheapest option	Not affordable to all low income earners	Not affordable to all low income earners	Not affordable to all low income earners
Multigenerational	No consideration	No consideration	No consideration	No consideration
Life cycle	No consideration	No consideration	No consideration	Some materials are recyclable
3. Appliances	**SHHA**	**Institutional**	**BHC**	**Private**
Media	None	Electrical	Electrical	Electrical
Entertainment	None	Electrical	Electrical	Electrical
Communication	None	Electrical	Electrical	Electrical
Incandescent	None	Most of the house	Most of the house	None
Fluorescent	None	Kitchen	Kitchen	Kitchen
CFL	None	None	None	Most of house

Part of the survey involved a needs assessment and the findings of the needs assessment study were compiled in table 7 overleaf.

TABLE 7: Needs Assessment

Stakeholder	**Level of awareness on the topic**	**Sustainability and energy efficiency**	**Materials, energy and technology**	**Barriers**	**Interventions**	**Level of need**

			innovation			
Policy makers	Med-high	Med	Poor	Bureaucracy	- Strategy - Plans	High
Regulators	Low-med	Poor	Poor	- Poor policy implementation	- Regulations - Incentive schemes	High
Implementers	Low	Poor	Poor	- Poor policy implementation	- Regulations - Incentive schemes	High
Suppliers	Low -med	Poor - med	Poor	- Awareness - Regulation	- Regulations - Education	High
Individuals	Low	Poor	Poor	- Awareness	- Education - Regulations	High
Stakeholder	**Level of awareness on the topic**	**Sustainability and energy efficiency**	**Materials, energy and technology innovation**	**Barriers**	**Interventions**	**Level of need**
Professionals	Low -med	Poor	Poor	- Lack of regulation; - 90% of low cost houses not designed by architescts - Awareness - Lack of capacity - limited research	- More research/innovation into local materials - Phased implementation - Demonstration/ prototypes - Public education - Specifications and regulation - Continued practice	Med - high

Consumption patterns of the different housing types revealed that the BOTEC house consumes less energy than the BHC and Council houses. The study finds this to be partly due to the bioclimatic design and partly due to the use of solar water heating instead of the conventional electrical geyser. Table 6 below shows the comparison of the different house types.

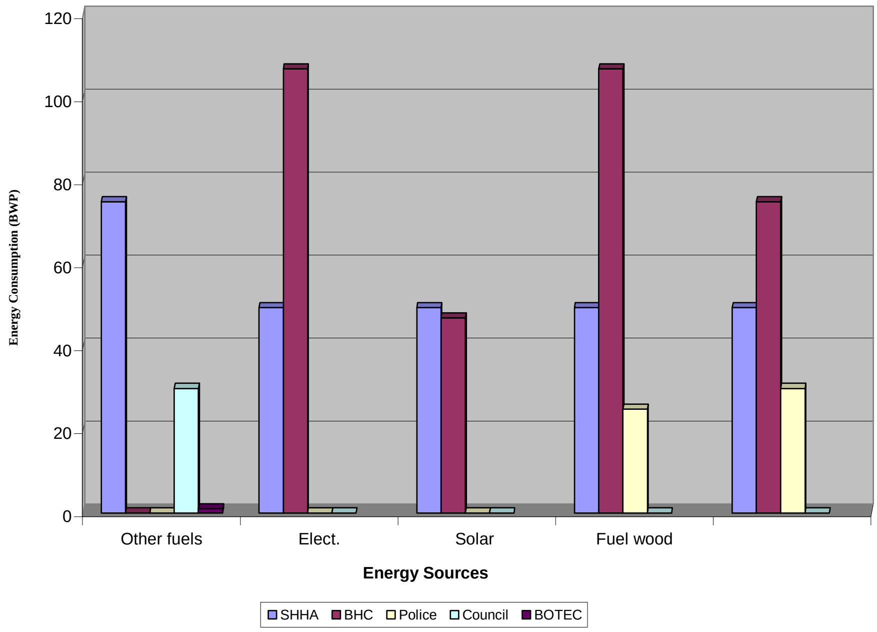
TABLE 8: Comparison of Energy Consumption

Low cost house type	**Qty sampled**	**Area of house (sq. m)**	**Average Electrical usage - monthly**	**Average Other fuels usage -monthly**	**Average water usage - monthly**	**Average Cooking fuel used**	**Average Heating & water heating fuel**
SHHA	20	42	0	75	39	Gas, paraffin	Fuel wood
BHC	10	45	107	49.50	49	gas	Gas
Police	5	48	47	49.50	24	gas	electric
Council	5	50	107	49.50	40	gas	gas
BOTEC	4	48	75	49.50	7	gas	none

Note: - Electricity of Police houses is subsidized

The consumption pattern is depicted in figure 27 overleaf.

FIGURE 27: Average Energy Consumption Pattern

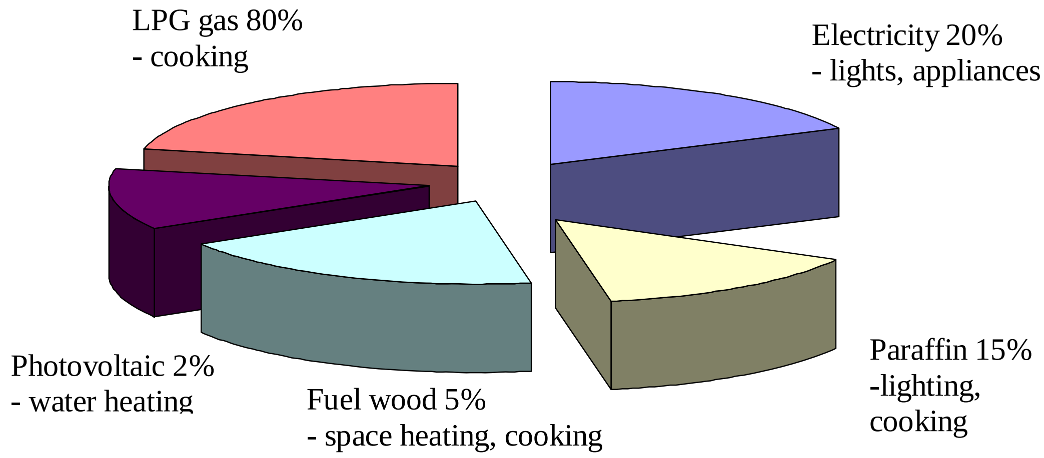


According to figure 27 above, police housing consumption is the lowest. However, the data was ignored because police housing services are subsidised.

4.4.3 Mix Energy usage

The percentages shown in figure 28 below indicate the average energy mix usage pattern by the low cost housing sector.

FIGURE 28: <u>Average Mix Energy Usage Pattern</u>



4.4.4 Lighting and Appliances

The appliances vary according the income and status of the owner of the house. On average, the common appliances used by low cost housing are listed below.

SHHA = TV, radio and kettle.

Institutional = Fridge, TV, DVD, radio, kettle and fan.

BHC and BOTEC = Fridge, TV, DVD, radio, kettle, microwave and fan.

Lighting usage patterns were summarised in table 7 below.

TABLE 9: <u>Comparison of Lighting Usage</u>

Low cost house type	**Lighting fuel**	**Light bulbs**	**Comment**

SHHA	Paraffin, candle	none	-
BHC	electricity	• Fluorescent kitchen only, • Rest of house - incandescent light bulbs	Need to adopt *CFL or LED light bulbs
Police	electricity	• Fluorescent kitchen only, • Rest of house - incandescent light bulbs	Need to adopt *CFL or LED light bulbs
Council	electricity	• Fluorescent kitchen only, • Rest of house - incandescent light bulbs	Need to adopt *CFL or LED light bulbs
BOTEC	electricity	• Fluorescent kitchen • CFL Rest of house • CFL external lights (latter w/ day light sensors)	*CFL has a long life and save cost. Need to adopt LED-bulbs in future. LED bulbs last 6 times longer than CFL; Cost effective in the long run.

* CFL = compact fluorescent lights

4.4.5 Interventions

The study identified proposals for interventions in table 8 below.

TABLE 10: Analysis of Possible Interventions

Intervention	**Energy saving**	**Comment/observation**
Design	Yes by all stakeholders	But implementation in stages. Selected because it will result in low energy usage and high energy savings
Lights	Light fittings	Selected by 80% of stakeholders Subsidised light fittings by institutions Use of day-light sensors preferred
Cooking	Most use gas	Present state sufficient
Water heating	Solar water heating by most	Initial cost high but long term saving and low maintenance Institutional workers can save on energy
Space heating/cooling	None	Effective design will require minimum space heating Only 2 to 3 months of cold weather Space cooling, taken care –off by design
Appliances	None	Needs to be resolved through standards

Further, the impact of using commonly used materials with sustainability in mind was investigated as shown in table 10verleaf.

Table 11: Considerations of Materials for Sustainability and Environmental Impact

1. Walls	**Characteristics/performance/ advantages.**	**Material attributes/ Environmental impact**
a. Clay Bricks used as stock brick or face brick; Size 222x75. Construction: double leaf, no cavity. - Most are imported from neighbouring South Africa - some bricks are locally produced - Also "dam" bricks from informal traders; fire them using primitive methods of firing located in a site near the Gaborone Dam.	a. slightly cheaper than concrete stock bricks b. The dam bricks are popularly used for decorative purposes in low cost dwellings e.g. verandahs or columns and paving. They come in various colours and textures. c. Reduced embodied energy d. Performance generally good, but not tested to standards such as SABS	***Disadvantages:*** a. Not tested and or approved by a regulating body b. Lack of consistency of quality c. Small scale industry, may not meet market demand if orders increase **Recommendations:** - "Dam" bricks need to be tested and Government to look for ways to subsidize the SMME producers to ensure standards are met. - Need for regulation - Need for standardisation for quality control and consistency
b. Concrete stock bricks; Size 222x75. Construction: double leaf, no cavity. - Some are imported from neighbouring South Africa - Most are locally produced	a. Strong and durable wall. Not liable to cracks compared to concrete block. b. Sometimes used as face brick finish e.g. for boundary walls. c. Double leaf wall construction offers good thermal mass	***Disadvantages:*** a. Expensive compared to local clay bricks b. Construction duration longer than blocks due to size
c. Concrete Blocks – - Most of the concrete blocks used in the housing construction industry are locally produced. 3 size types are manufactured as precast (off –the-shelve) or insitu. Sizes: 41/2, 6 and 9 inch blocks. Few blocks are imported from South Africa	a. Cheaper than stock bricks b. Easy to use and quick erection c. Can be produced in situ d. Medium to high thermal mass	**Disadvantages:** Tends to crack when used on load bearing walls; esp. when there is no lintels or reinforced beam provided **Recommendations:** a. Need for research into alternative blocks which use local materials; such as the BOTEC Kgalagadi sand block and Hydro- form block

Table 11: continued

1. Walls continued	**Characteristics/performance/ advantages.**	**Material attributes/ Environmental impact**
Earth (mud) blocks come in various sizes and are hand made.	Traditional material. Not common in urban houses. Has good thermal mass • Uses soil from the site (recycling) • Locally available May need to use local soils to produce a good block in the lines of Hydroform block from South Africa	***Disadvantages:*** a. Not tested and or approved by a regulating body b. Poor consistency in quality **Recommendations:** - Need for regulation and Standardisation for quality control - Need for research into stabilisers and mass production
Hollow clay blocks – not common in Botswana. Sizes: 41/2, 6 and 9 inch blocks.	Has high thermal insulation value; hollow provides cavity insulative properties	**Recommendations:** It would be good for variety of materials
2. Floors	**Characteristics/performance/ advantages.**	**Material attributes/ Environmental impact**
a. Concrete floors are popular for current houses: of 150 mm concrete floor slab on 100 mm hardcore with 20/25 mm cement screed finish.	a. Cheaper and appropriate for low cost housing b. Good thermal mass	**Disadvantages:** None noted
b. Mud and cow-dung floors are popular for traditional dwellings. Composition: Mud or cow-dung screed on compacted hardcore	a. Scarce and not used in urban areas b. Cool to the feet	**Disadvantages:** a. Scarce materials and not popular material in urban areas b. High maintenance **Recommendations:** Research innovation needed

Table 11: continued

3. Roofs continued	**Characteristics/performance/ advantages.**	**Material attributes/ Environmental impact**
a. Corrugated iron (zinc)	a. Cheaper than most roofing	**Disadvantages:**

- profile sheets	materials	a. Poor thermal performance b. Imported - high embodied energy **Recommendations:** a. Ceiling b. Insulation c. Reflective paint
b. IBR profile sheets	a. Relatively cheap b. Popular	**Disadvantages:** a. Poor thermal performance b. High embodied energy, from South Africa or Zimbabwe **Recommendations:** a. Ceiling b. Insulation c. Reflective paint
c. Clay tiles	a. Variety of colours b. Attractive finish c. Average thermal - performance compared to metal sheets	**Disadvantages:** a. Expensive compared to metal roofing sheets b. Imported - high embodied energy **Recommendations:** a. Ceiling b. Insulation c. Light coloured roof
4. Ceiling	**Characteristics/performance/ advantages.**	**Material attributes/ Environmental impact**
a. Rhino board	a. affordable to low-medium income groups b. good thermal properties	**Disadvantages:** a. Expensive b. Imported - high embodied energy **Recommendations:** a. subsidize b. research for alternatives

Table 11: continued

4. Insulation	**Characteristics/performance/ advantages.**	**Material attributes/ Environmental impact**
Wood wool	a. affordable to low-medium	**Disadvantages:**

	income groups b. good thermal properties	a. Expensive compared to Rhino board b. Imported - high embodied energy **Recommendations:** a. subsidize b. research for alternatives
5. Doors/windows frames	**Characteristics/performance/ advantages.**	**Material attributes/ Environmental impact**
a. Steel	a. affordable to low-medium income groups	**Disadvantages:** High embodied energy **Recommendations:** None
b. Aluminum	a. affordable to low-medium income groups	**Disadvantages:** a. Expensive compared to steel b. high embodied energy, all imported from South Africa **Recommendations:** a. none
c. Timber	a. aesthetically pleasing b. variety of sizes and styles	**Disadvantages:** a. Expensive compared to metal b. Imported - high embodied energy. c. High maintenance **Recommendations:** Not recommended for low cost housing for Botswana

4.5 DATA ANALYSIS AND SYNTHESIS

This section of the study analysed the collected data from observation studies and survey research in an aim to address the research problem.

The current low cost housing and industry in Botswana was found not to support sustainability and resource efficiency. There needs to be improvement in the coordination of various stakeholders in housing. Some of identified challenges included poor building practice, poorly performing houses, land and housing shortages, poor provision of amenities and lack of knowledge with regards to sustainability and resource efficiency.

Low cost housing must be conceived from considerations for the region and the locality. Regional aspects such as the local climate data are valuable to the local construction industry and are possible areas for further research in Botswana. Further, low cost housing is generally low density with the majority of housing being single dwelling on single plot resulting in land and housing shortages. The population of Botswana especially the urban population is growing rapidly and there is a growing demand for housing. However the majority of low income earners cannot afford housing. Existing finance schemes are limited as they do not accommodate all the poor. There is room to investigate alternative finance schemes such as the sweat equity and green finance.

Current housing design is not suited to the local climate resulting in housing that is hot in summer and cool in winter. Conventional housing can draw lessons from indigenous architecture and consider simple interventions such as orientation and planning of spaces to support various living functions. Housing must be conceived by lifestyle rather than by design. Further housing design must take into consideration the building life cycle. The building must be designed to adapt to change, consider post occupancy and consider recyclability or re-usability of its components or materials.

There is a lot of resources that are not directly associated with housing however are consumed by housing such as water and energy. Although the low cost housing sector is already using mixed energy, all stakeholders confirmed the need to implement sustainable and energy efficient systems for social, economic and environmental reasons.

Currently low income earners cannot afford energy and thus their health and quality of life is compromised. Solar water heating is not affordable to the majority of low income households as it has high initial costs. It is generally found in institutional low cost housing and high income housing. Further, the practiced mix use energy is unsustainable as it encourages the depletion of fossil fuels and some planned strategies in energy are unsustainable such as the rural electrification programme.

Current resource usage was found to be of high embodied energy. The majority of resources are sourced from neighbouring countries, including electricity and materials. Botswana is a drought stricken country. There is need for resource efficiency and conservation. Local materials are currently under utilized mainly due to lack of research and innovation. Research and innovation will lead to the development of local knowledge, employment creation and reduced impact on the environment.

The study acknowledges the importance of affordability when considering sustainability and resource efficiency for low cost housing.

4.5.1 Identified barriers

The major issues regarding sustainability and energy efficiency in urban low cost housing of Botswana are due to:-

a. Poor implementation of policy and legislation.
b. Poor building performance.
c. Poor consumption and conservation strategies.
d. Poor research and documented information on local resources.
e. Poor building practice.
f. Lack of support structures.
g. Lack of awareness.

4.5.2 The Support system

Botswana is signatory to a number of global protocols on sustainable development. However there is slow in integration of these into policy and legislation. Hence current building regulations and standards do not support sustainability and resource efficiency. Poor implementation is augmented by poor maintenance programmes.

4.5.3 Mitigation

A few national strategies are in place and some are in the process of being established. The national vision 2016 supports socio-economic equity and the protection of the environment. The study identified the following mitigation strategies.

1. Public education, awareness strategies and continued professional practice.
2. Implementation frameworks to improve projects, building practice and programmes.
3. Research.
4. Regulation
5. Monitoring and evaluation.
6. Incentive schemes.
7. Creative finance schemes.

4.6 VALIDATION

Validation was intended to identify bias that may have been built into the data. The questionnaires and interview questions were reviewed for bias including perception, sample selection and size, generalisation and to weed out open ended questions. The study further conducted pre-testing of user and interview questions to reduce bias.

Chapter 5

CONCLUSION

5.0 BACKGROUND

Sustainable, energy conscious design of housing makes a considerable difference to the building's thermal performance, user comfort, health, appropriate use of resources and the environment. It results in cost savings for services by the occupants, reduces institutional expenditure on programmes and maintenance costs, and reduces the negative impact on the environment by the building sector.

Following the research, the study found that for successful integration of sustainability and energy efficiency in low cost housing for Botswana, there must be a balance in the integration of three primary elements:-

- Energy efficient housing.
- Culture and regional identity.
- The Environment.

Evidently, sustainability is a complex issue and its challenges are enormous. The research recommends a phased approach for Botswana, to cater for limitations such as availability of resources. The study recommends that institutional housing be targeted first, as the Government of Botswana is responsible for a large portion of low cost housing through BHC and institutional staff housing. The government is also the largest employer in the construction sector of Botswana. This view is supported by the EECBS pre-project study.

The study recommends the facilitation of an enabling environment for the various sectors of institutional low cost housing, through the integration of three primary elements of sustainability.

5.1 INTEGRATED HOUSING

A top-down decision making approach does not promote change or integration of new concepts to existing systems. There is need to establish tools that can be used to influence change, including systems for monitoring and evaluation of projects. Further, to establish a national coordinating agency that has proportional representation of the various residential sectors that exist in Botswana to ensure involvement at various levels including macro, meso and micro.

5.1.1 Towards Integrated Housing

The planning and design of low cost housing must go beyond the provision of the basic shelter. It must be holistic with considerations for the locality, optimal building performance, human thermal comfort, efficient and effective use of resources and the impact on the environment. The following parameters for integrated housing for Botswana were identified:-

a. Land utilisation must be planned with respect to context, land type and tenure.

b. Site selection considers existing features such as orientation, topography, prevailing winds, surrounding buildings and vegetation are important to consider prior to design. These will also be dependent on other aspects including local building regulations and standards, movement patterns, community foci, and services.

c. The form, size and type of housing. Housing density needs to be increased towards medium and high density to integrate mix of housing types such as cluster and mixed use. Also to ensure sustainability of resources such as land, transport and amenities. Further, increased density and variety of housing makes housing accessible to the majority of people.

d. Urban housing blocks that offer mix use functions like commercial sector in the lower floors and offices and residential on top. This will decrease travel distance, make use of services that are already provided for the commercial services available to households by night, keep the city occupied at all times.

e. Considerations for climate and the building envelope. The design of the building envelope needs to be informed by the local climate. Interventions on the elements of the building envelope such as the roof, openings and the choice of materials need to be considered at the conception of the design. Sloping of the roof towards prevailing winds maximises air movement on the external surface of the building. Painting of the roof with reflective paint reflects solar radiation away from the building thus reducing heat gain inside the building. The thermal stability of the building may be improved by various strategies including the ceiling (with or without insulation), appropriate location of openings such as doors and windows to encourage natural ventilation, placing few windows on the south and west façade and application of solar shading strategies such as vegetation or solar control devices.

f. Building layout. The building plan needs to be affordable and resources efficient. This can be achieved by building shape, a compact plan, shared walls (detached housing or flats), and appropriate location of rooms by function (utility rooms used to shelter living spaces). The quality of external spaces must support outdoor living by providing shaded, semi-private and private spaces. For sustainability, housing must also be multigenerational catering for change.

g. Resource efficiency and conservation. Design must integrate associated functions such as cooking, water heating, space heating and cooling and sanitation. Medium to high density housing reduces the capital cost of incorporating alternative/innovative energy technology and appliances such as solar water heating and CFL light bulbs

h. Affordability. For sustainability to be achieved the design of housing must be conceived with cost in mind. Affordability and access to funding were found to be some of the key challenges for sustainable, energy efficient housing in the low income sector of Botswana. The common perception is that it costs more to develop energy efficient housing and there are no known examples to prove otherwise. However, research in a similar context as Botswana has demonstrated that it does not have to cost more. Even when it does cost a bit more, the savings are real and through life cycle cost analysis payback periods have been determined. According to the EECBS Booklet current energy consumption figures for the domestic sector of Botswana stand at 495,026 MWh and cost BWP168, 209,838 per year, due to poor design and planning. The estimated energy reduction from changes in the design approach is estimated to be 164,155 MWh, equivalent to BWP 55,779,877 per year. The payback period is estimated to be about 2.08 years, at an intervention cost of BWP11, 620,808.

i. Viability is important when assessing the value of sustainability and resource efficiency in housing projects. According to the PEER (2000) studies, the viability of energy efficiency has been established. Important aspects that were identified include adequate design, skills, life cycle costing, monitoring and evaluation.

j. Support systems. Sustainability and resource efficiency will current housing assistance schemes like the SHHA scheme through establishment of creative and innovative housing finance schemes. This approach can be achieved through awareness raising and capacity building, as part of a strategic intervention processes.[68] According to the South African Department of Housing White Paper of 2000, there is need for a collaborative effort which includes

[68] Tumisang, H. (2005).

amendments to existing housing guidelines, control codes, policies and putting in place incentive schemes.

5.1.2 Environmental impact

Building materials account for two-thirds of the total cost of the house and for materials sustainability and reduce the impact on the environment the following aspects of materials need to be considered for future design and research:-

a. Local and indigenous materials are easily accessible from forests and fields at little or no cost, systems for replacement of resources need to be in place to avoid depletion.
b. Some traditional materials like burnt clay bricks and tiles, bamboo, lime and timber need to be researched for potential uses and additional innovation in the construction of housing.
c. Innovative techniques of construction need to be pursued that meet Botswana's climate and needs.
d. Self-built housing will reduce the cost of labour and lead to employment creation. This participatory approach can be achieved with guidance and can lead to capacity building and employment creation for some of the country's 30% none employed.
e. Properties and characteristics of materials need to be established when selecting materials, to avoid transport and embodied energy.

In terms of energy, the EECBS pre-project case studies indicated that the source of increase in energy use by residential buildings is mainly due to an increasing dependency on electricity. The general uses for energy in the residential sector are cooking, water heating, lighting, and space heating or cooling and the running of appliance such as fridges, fans, kettle and TV. Energy consumption findings of this study have confirmed these findings.

Electricity usage impacts on dwindling fossil fuels and expenditure on energy and energy consumption can be reduced in a number of ways including:-

a. Alternative energy sources; renewable energy sources for water heating, cooking, additional space cooling and heating and lighting are recommended.
b. Equipment and Installations; considerations for properties, characteristics, source and quality must be predetermined to match the overall design requirements and for sustainability.
c. Methods of installation; methods of installation must be assessed through simulation, at design level to ensure quality of design and efficiency of performance
d. Building simulation methods must be used to assess the projected building consumption prior to construction.
e. Life cycle costing must be calculated at the design stage of the building and the projected pay-back period be noted.
f. Building management systems for operation and maintenance such as Building Energy Management Systems for large projects.
g. Incentive schemes

Government subsidies have a role towards uplifting of urban low income housing, and a strategy for the development of Incentive Schemes need to be developed in line with planned legislation and policies towards sustainable energy efficient housing.

- Grid share, there is potential for the building user to sell excess alternative energy to the national grid.
- Tariff grading, depending on level of sustainability of the design of the house, the user could have reduced electricity tariffs
- Green financing, where by those intending to submit sustainable design housing developments (individual or developer) get preferential bias for access to certain finance systems.

The environment can be protected by consideration of the following aspects in housing:-

a) The selection of materials, their mining process, transport and embodied energy.
b) Controls can be incorporated for large projects to introduce efficient use of materials, appliances and equipment in the following ways:-

- Lighting controls, in the form of light/human sensors allow for resource conservation and enhance quality of life of the occupants,
- Automatic controls for windows allow the building envelope to self-regulate.

c) Recycling and re-use of building and materials allows for the building's use to be able to be changed without major alterations at reduced cost and time.[69]

d) Deconstruction with minimal or no impact on the environment, using developed mechanisms or adopted mechanisms.

The study recommends the integration of sustainability and resource efficiency in the low cost housing sector because low cost housing accounts for approximately 60% of the housing sector of Botswana. For better impact, the process must start with institutional housing as it is a sector with adequate resources for implementation towards best practice. Implementation instruments such as the output of this study, the framework for the incorporation of sustainability and resource efficiency in the low cost housing sector can be introduced through a phased approach and lead to regulation and incentives.

Implementation tools must be accompanied by monitoring and evaluation systems such as post occupancy surveys and audit programmes such as building audits and energy audits. The information collected from these systems must be used to inform future projects.

[69] Gibberd, J. (2003).

Chapter 6

THE FRAMEWORK

6.0 INTRODUCTION

The output of this study is the framework for sustainable, resource efficient design for low cost housing of Botswana, which is intended for the integration of sustainability and energy efficiency into the existing housing system.

6.1 THE PURPOSE OF THE FRAMEWORK

The purpose of the framework was to provide guidance on the integration of sustainability and resource efficiency in housing. It is intended for use in conjunction with existing structures national strategies and housing master plans. The integration is intended to improve housing delivery and accessibility leading to quality affordable housing that is suited to its environment. The spin-offs are many including human comfort, better health and enhanced quality of life for occupants.

6.2 TARGET MARKET

The government is the biggest player in the economy of Botswana and the construction sector. The government, through the Department of Buildings and Engineering Services (DBES) is mandated to build substantial staff housing for the various government departments that lie outside the main urban areas such as Gaborone and Francistown. Even for the latter, the government builds substantially through its parastatal body BHC. Hence, the study recommends that the integration of sustainability and resource efficiency must start at institutional level for good impact. For the purpose of this study the institutional sector includes all government, parastatal institutions and council staff housing.

6.3 THE FRAMEWORK

The output for the study is the framework for sustainable, energy efficient design for low cost housing of Botswana. It is coupled with the proposal booklet which provides documented information on housing that is suitable for Botswana. The framework is a non-exhaustive tool that addresses specific conditions set out by this study.

The framework is guided by three identified primary elements of sustainable development, namely culture and regional identity, resource efficiency and preservation of the environment. These elements were balanced by socio-economic aspects to cater for the low income sector.

6.3.1 Culture and Regional identity

The region and its natural environment are key factors to sustainable development. Hence, policy, regional master planning and environmental impact assessments are important for building development. New developments must relate to surroundings and other planned activities.

Existing natural vegetation, wildlife and natural resources must be recognised as part of the site and conserved rather than destroyed during excavations and the construction process. Plans and new developments must consider natural elements found on the site such as contours and the water table. The neglect of natural conditions results in high cost of excavation and foundations, alterations to the natural drainage, wind movement throughout the site and disturbance to the natural flow of water.

Appropriate design of housing provides rich, quality spaces. It allows for hierarchy of spaces such as private spaces, semi-private spaces like courtyards, public spaces as found in the traditional settlement. The majority of the low cost housing dwellers tend to use the outdoors as a living and entertainment space. Design must support the culture and social structure of the people, offering visual connections to support communal living that is inherent in the African tradition and be functional. Changes in material can be used to indicate hierarchy of routes or spaces.

The settlement or neighbourhood must be related to the core or city centre or sub-centre through movement linkages. This will reinforce its connection to central activities such as assembly points, media centres, recreational facilities and shopping centres.

6.3.2 Housing for Botswana

Diversity of housing through mixed use developments is necessary for sustainable housing. While there is mixed planning of housing developments in Botswana, further diversity can be achieved through increased density and modes of tenure. Increased density will cater for the growing housing demand. Currently, in Botswana there is a social preference of one dwelling per plot that is further encouraged by the planning system. Hence, the introduction of higher density housing at institutional level is a good starting point.

Diverse solutions for tenure will cater for the diverse urban housing population and evolving household types. Modern Botswana households are also diverse with family, single-parent family, bachelor and shared housing.

6.3.3 Resource efficiency and Preservation of the Natural Environment

The design of housing with considerations for resource efficiency and the natural environment leads to sustainability. It is reinforced by appropriate design with the climate of the locality. Key parameters to be taken into consideration are:-

i. Thermal performance of the building envelope is vital to support the indoor environment. People perform well in well-conceived spaces that protect them from the elements. These are spaces that are not too hot in summer or too cold in winter.

ii. Air quality through ventilation within the building enhances the thermal performance of the building and fresh air is vital for health and reduces concentration of bacteria and chemicals. Natural ventilation includes windows that are open-able and that are designed with a certain degree of control by the occupant in order to achieve human comfort. Cross ventilation is easy to achieve in housing and can be augmented with night time cooling through stack effect which takes advantage of diurnal changes in temperature at night.

iii. Bioclimatic architectural design including appropriate orientation, shape, shading, glazing, lighting, acoustic comfort and thermal mass to optimize the building envelope. Further, design that is appropriate, innovative and caters for efficient use of natural resources such as land, materials, water and energy. In order to reduce the embodied energy of products the emphasis must be on local resources and conservative use of resources through conscious thought. Recyclability, durability, adaptability, re-use and longevity must be at the core of design.

6.3.4 Socio-economy

Current housing is accessible only to those who have jobs and earn adequately to meet the SHHA housing scheme. There is no provision to house the lower income bracket. Also sustainability and resource efficiency is currently unaffordable for the majority of the low income sector.

This study identified a need for the creation of an enabling environment. Low cost housing must consider socio-economic aspects such as design, choice of materials, construction method and financing scheme. Botswana needs creative alternative finance solutions such as green financing, budgetary incentive schemes and sweat equity. The schemes must be implemented through a gradual process. Once the sector structure has been established, the structure must be translated to other sectors through a collaborative effort with stakeholders such as Councils who have jurisdiction over building plans.

6.4 PROPOSED BOOKLET

The proposed booklet "Guideline Booklet on Sustainable, Resource Efficient Design for Low Cost Housing in Botswana" is a spin-off from the study output. It serves as documented information on sustainable and energy efficient low cost housing that is suitable for Botswana.

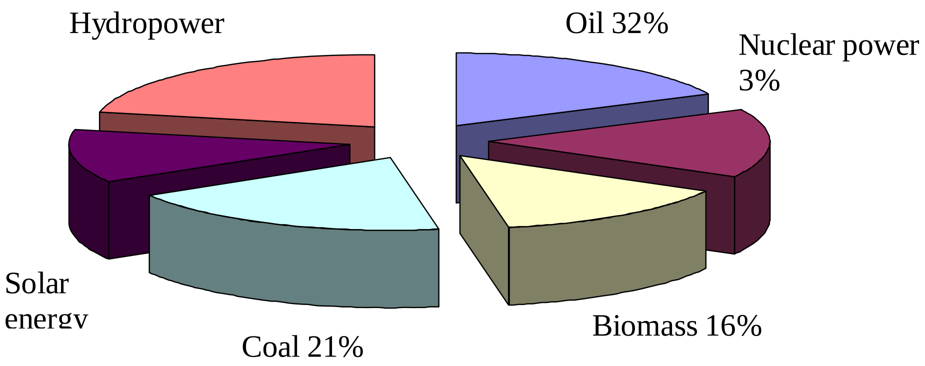
The booklet demonstrates sustainable practices through strategies that can be introduced at various stages of the housing process. Some of the strategies do not require additional costs to the normal construction cost if implemented for new housing, including orientation, building shape and form and location and size of windows.

The booklet will include elements of resource efficiency because the residential sector consumes a lot of basic services such as water and energy. Houses consume energy through basic functions such as cooking, lighting, space cooling/heating, appliances and water heating; energy consumption is catered for in this booklet. Household energy consumption for space heating and cooling alone can be reduced by 50 to 70% through energy efficient design. Hence, the sensitive consideration for resources at implementation, construction and post construction phase contributes to the reduction of negative impact by resources on the environment. For example, it reduces the depletion of the world's resources such as fossil fuels and reduces the degradation of the environment by way of mining and manufacturing of materials for construction of houses.

6.4.1 Consumption status

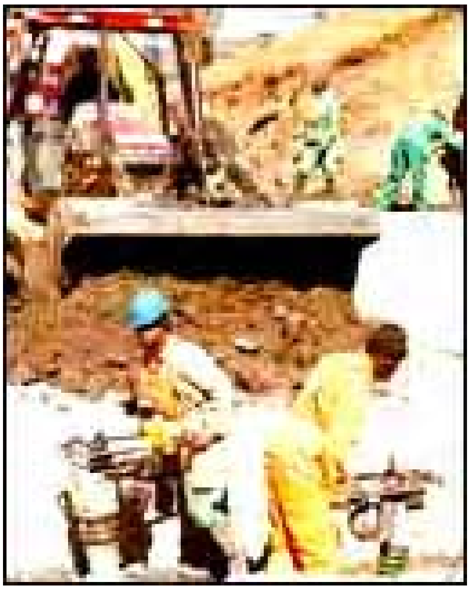
There is a significantly high global dependency on fossil fuels with approximately 40% of the energy used to support the construction sector through mining, the processing of materials, construction, transport and for household functions. Figure 29 and 30 overleaf; show the current global dependency on fossil fuels and an example of how the construction sector uses energy.

FIGURE 29: Global energy consumption patterns



Source: Ward, S. (2002)

FIGURE 30: Energy Consumption for Construction



Source: Ward, S. (2002)

In Botswana, statistics show that in addition to the planned Village Electrification Programme, the Botswana Power corporation (BPC) growth projections show increased targets for electrification of SHAA areas in Gaborone and Francistown. According to the BPC Annual report of 2004, the following is the status:-

- 90 % of the electricity connections were domestic sector.

- 70 % of the country's electricity is imported from surrounding countries e.g. South Africa and Namibia.
- There is a possibility of none availability of electricity source from South African due to the increased demand for post independence electrification programmes in that country.

6.4.2 Design solutions

There are factors that must be considered when designing house for sustainability, energy efficiency and human comfort. There needs to be considerations for climate, temperature, humidity and prevailing winds of the locality.

1. The climate of the region

The climate of the locality is documented by recording characteristic weather conditions over an extended period of time. The climatic data is expressed in terms of solar radiation, temperature, humidity and wind pattern. The data needs to be taken for a period of time to cater for variations over time and to be of utmost benefit to the design. The building is then designed to respond to the local climate, in similar fashion to the traditional house. The design should consider the intensity and duration of solar radiation. This factor determines the likely heat gains by the building and the availability of solar energy systems such as water heating systems. The amount of radiation is determined by the angle of incidence of the sun which is in turn derived by from the relative solar path of the sun, as shown in the seasonal movement of the sun figure 22.

- The more acute the angle, the less solar radiation
- The longer the solar path length, the less the solar radiation
- The more the pollutants or water vapour on the atmosphere, the less the solar radiation

The amount of solar radiation is determined by several factors identified below:-

- The duration of sunshine for a particular location
- The topography and orientation of a site or building. For example: a house on a north slope receives more radiation than one on a south facing slope.

- The seasonal movement of the sun. In winter the sun has a much smaller arc on the horizon than the summer sun. And for Botswana and the Southern African region; in summer the earth is much closer to the sun.

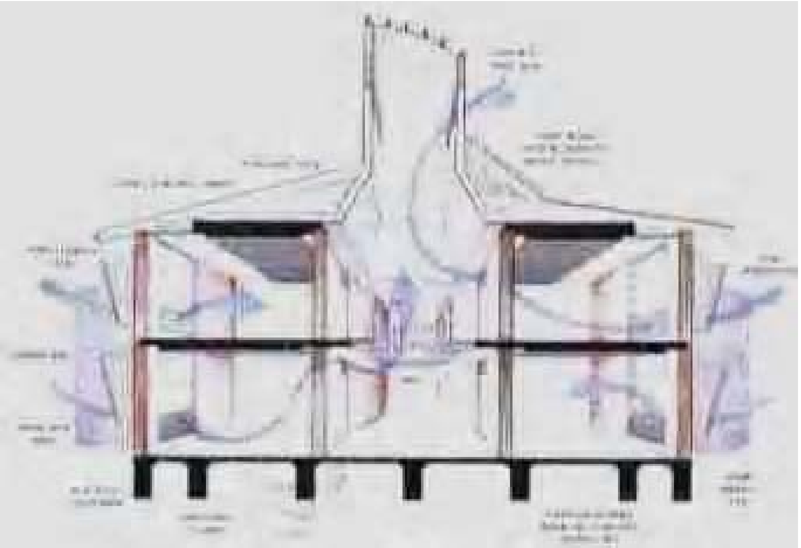
2. The temperature of the region

Temperature, in general, measures heat or the lack of it, and it is affected by solar radiation depending on humidity and the level of exposure to winds. Solar radiation gain through the building envelope and materials causes temperature to rise. Material properties, colour, and texture respond differently to solar gain because materials have different absorptive or emissive capabilities. Similarly, wind affects surfaces differently; for example dark, coarse surfaces absorb more heat during the day than smooth light surfaces.

Temperature can be controlled by the application of solar control devices and vegetation. Also at night, the temperature drop as a result of lack of solar radiation can be used to advantage for stack effect to cool the housing block or even a group of housing blocks, as shown in figure 31 overleaf.

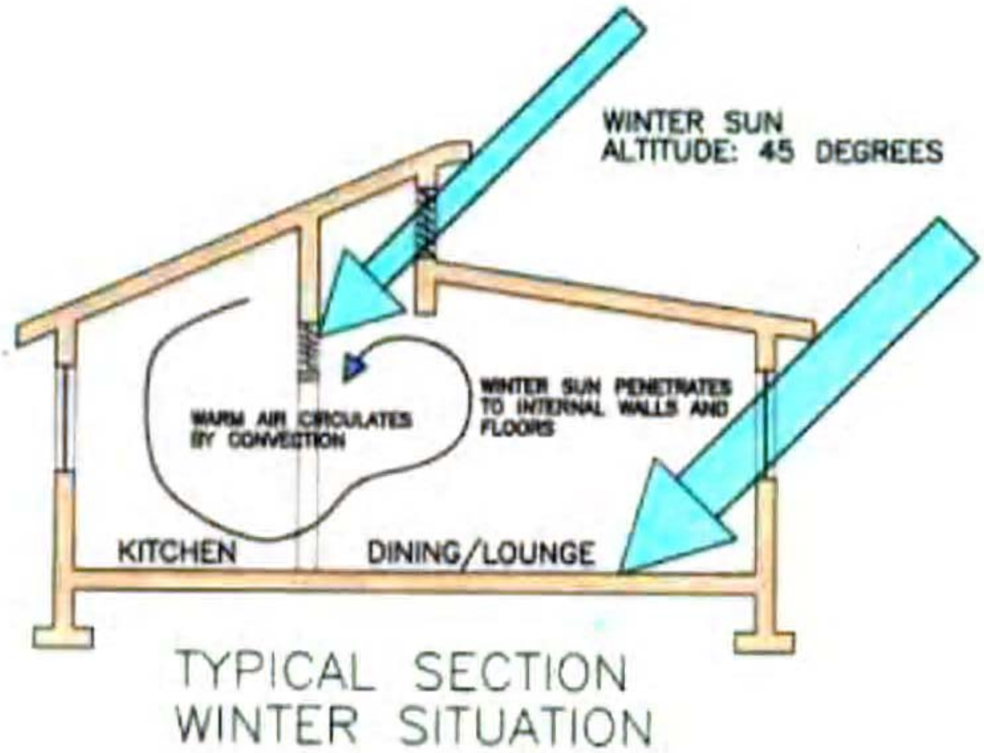
FIGURE 31: Stack effect

(a) Summer stack effect, sketch



Source: Tshupelo, C. (2005)

(b) Winter stack effect



Source: BOTEC Experimental Staff housing Report (1992)

3. The relative humidity of the locality

Relative Humidity is determined by the amount of water vapour that is in the air and this knowledge can be used to achieve human thermal comfort; as relative humidity combined with high temperatures results in human discomfort. Humidity levels depend on local climate. That is, the presence of water and vegetation. For Botswana, the hot and semi arid climate can be moderated by evaporative cooling and vegetation.

4. Prevailing winds

Wind causes movement of air from areas of high pressure to areas of low pressure and wind patterns are derived from the topography of the area, depending of the position of the site in relation to the surroundings such as mountains, hills, trees and rivers. Wind can cause temperature fluctuations since hot winds cause heat gain, while cold winds cause heat loss. Hence, prevailing winds of the site must be exploited for building ventilation in order to improve human thermal comfort.

- The summer strategy is to ventilate the housing block through cross ventilation by way of air convection.
- The winter strategy is to avoid heat losses through infiltration (air seepage through doors and windows).

Botswana lacks documented information for climate data. The study recommends research into local climate and wind mapping that may be done through collaboration with strategic partners such as the Meteorological Services Department.

6.4.3 Planning and Design Strategies

Planning of housing must look at the house in relation to its surroundings in terms of scale, use, density, environmental aspects and place-making. The site and house must be protected from the weather such that it is shielded from the wind and the harsh summer sun, while allowing the winter sun.

1. Planning and zoning

a. Regional planning aspects must inform the design; consider prevailing winds, orientation of the site and or the building, surrounding infrastructure and the landscape.

b. Zoning of the site and or building for optimum building performance and also the zoning of the building spaces and openings.

Sustainability is even more critical in urban areas due to densities and land shortages.

Housing location must avoid overshadowing by neighbouring buildings.

2. Bioclimatic design

Bioclimatic design is design of the building envelope for optimal sustainability and resource efficiency, while reducing the impact on the environment. It results in a building envelope that is stable and slow to react to thermal changes. The strategies employed are elaborated below:-

a. Thermal mass for walls, floors and roofs. Thermal mass is vital to ensure thermal stability within the housing block. Some common good thermal mass is possible in existing materials such as mud, concrete blocks and bricks. These elements can be enhanced through the following strategies:-
    - Reflective, light colours to avoid excessive heat gains in summer.
    - Smooth surfaces to avoid excessive heat gains in summer.
    - Insulation to increase thermal stability and to avoid cold bridges in openings.

b. Medium/High density and compact layout.

c. Appropriate material, size, location and number of windows:-
    - Single or double glazing: double glazing reduces solar radiation but is expensive. The study recommends single glazing with proper location and sizing of windows; minimum (20%) windows on south and west façade. It further recommends the use of solar control devices such as vegetation; they cost little or nothing but are effective.
    - Recessed window and door openings especially for south facade.

d. The use of materials with good insulation properties for the roof, walls and floors. Appropriate materials may require small additional costs to the construction cost. However, it has annual cost savings and short pay-back period.
    - Avoid dark coarse materials.
    - Use reflective, light coloured materials for areas of the housing block that receive most solar radiation e.g. roofs and south-west walls.
    - Insulated ceiling.
    - Solar water heaters. Medium to high density housing developments make this an affordable choice of energy and make the technology accessible to the low income sector.
    - Select materials for the full life of the building and consider recyclability and deconstruction phase of the building.

e. Roof ventilation. Air in the roof acts as further insulation and helps to regulate the temperature.

f. Solar control/shading of building protects various areas of the housing block. This can be applied through overhangs, sun control, vegetation and solar shading devices.

g. Natural lighting should penetrate most of the housing block because it is ideal; it is comfortable to the eye and costs nothing. The treatment of additional lighting and needs to be sensitively designed to save energy and various techniques used like task lighting, change from incandescent to energy efficient light bulbs and occupation sensors should be introduced slowly into the system as a strategy to reduce energy demand and for cost savings.

h. Equipment and Appliances need to be selected for their sustainability, water efficiency, energy efficiency and environmental value. For example, heat gain from lights and appliances needs to be resolved as part of the design process and this is achievable through medium to high density low cost housing.

i. Ventilation can be achieved by correct location and sizing of openings relative to prevailing winds. Sensitive design avoids infiltration of air and or wind through openings as they result in temperature fluctuations.

j. Screening of the housing block can be achieved with vegetation, correct location of the housing block or blocks and design that considers the surrounding environment.

3. Energy

Alternative energy and in particular, renewable energy sources, need to be considered for housing as they save cost and reduce the demand on already dwindling resources. Information on common renewable energies that includes properties, cost, pay-back time and benefits compared to conventional is readily available in the market. The cost of energy is attributed to the various forms of energy use. There are:-

- Direct costs – costs related to end use energy.
- Indirect costs – costs related to the indirect use of energy.

Some of the cost comparisons are demonstrated in table 12 and 13 below.

TABLE 12: Cost and Life span Comparison for Lighting

Basic Information	**LED-bulb**	**12W CFL**	**60WGLS**
Unit cost	R40.00/lamp approx.	R12.00 /lamp	R1.70/lamp
Life expectancy	60,000 hours	10,000 hours	1,000 hours
Energy consumption		12 kWh	60 kWh
Energy cost	Less than R3.36	R3.36	R16.80
Greenhouse gas equivalent (CO)	Less than 21.53 kg (Plus no mercury)	21.53 kg	107.63 kg

Source: Ward, S. (2002) and http//www/helioint reports/feb11/2008

TABLE 13: Cost and Life span Comparison for Water Heating

Solar water heaters	Life cycle costing = 5 years	Approximately R6000 incl. maintenance costs.
Conventional geyser	Life cycle costing = 5 years	Cost per month = R93 Cost over 5 years = 6,813.29

Source: Ward, S. (2002)

The return on investment for using solar water heater is approximately ZAR 800 (equivalent to BWP 896). This refers mainly to the financial benefit. However, there are other benefits like the benefit to the environment.

It is important to identify the energy needs of low cost housing development and how they are related to design and the overall running costs of the house, as types of energy uses in residential buildings need to be rationalized by the designer early in the design process. Once the needs are identified various related aspects are addressed like sustainability and resource efficiency measures like energy efficiency and energy conservation. This way end use energy can be rationalized and decisions can be made for basic uses such as lighting, cooking, water heating, space heating or cooling, equipment and appliances. The actual cost of running the housing block, equipment and or appliance can then be calculated through life cycle cost analysis.

6.4.4 Intervention Strategies

Interventions named above can be implemented in phases in new projects or as retrofits for existing institutional low cost housing. The study recommends a phased approach due to limited resources.

1. Short term intervention

a. Orientation - Free
b. Insulated ceiling - some cost
c. Size and location of windows - Reduce cost
d. Low energy light fittings - Initial cost; Long life, energy savings
e. Wind shield such as vegetation and courtyards - Little or no cost

1. Intermediate Interventions

The techniques suggested in this section have more benefits than the basic interventions mentioned above, yet the implementation cost does not deviate much from the construction costs and is recoverable in a short space of time of approximately 5 years. These are:-

a. All Short term intervention in (1) above.
b. Solar water heater - Initial cost; no operational cost
c. Roof overhang - Little cost

2. Long term Intervention

Long term interventions lead to the full benefit of bioclimatic design and to be justifiable, they are best implemented for new buildings.

a. All intermediate measures.
b. Wall insulation.
c. Cavity wall.
d. Solar control devices.
e. Introduction of diffused lighting.
f. Renewable energy for space heating/cooling.

6.4.5 Benefits for Low Cost Housing

The benefits of sustainability and energy efficiency in housing development are numerous and a few are mentioned below.

1. Benefits to Individuals
   a. Human indoor comfort, from housing that responds to climate, context and the surroundings.
   b. Health benefits through good air quality, natural lighting, no rising damp, adequate temperatures for spaces.
   c. Cost savings from reduced running costs for energy and maintenance.
2. National Benefits
   a. Delayed need for more power generation plants.
   b. Reduced need for importing of power from neighbouring countries such as South Africa and Namibia.
   c. Cost savings from reduced energy demand
   d. Improved health for the nation and less demand on national budgets.
3. Environmental benefits
   a. Reduced impact on the environment as less energy is used.
   b. Reduced level of pollutants released to the atmosphere.
   c. Reduced risk of depletion of non-renewable energy resources.

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APPENDIX INDEX

APPENDIX 1

Energy profile

The energy situation in Botswana is like that of most developing countries; with fuel-wood as the main source of energy for the low cost and rural sector. In 2001, 50% of urban low cost houses were reported to use fuel-wood for cooking.[70] Heavy reliance on wood has resulted in shortages and is often associated with deforestation. In general, the residential sector is the largest energy consumer followed by industry and transport. However, in terms of electricity consumption, the mining sector is the largest consumer, followed by commerce and residential sectors.

Botswana is faced by the challenge of limited supplies of energy. Seventy percent of electrical energy is imported from neighbouring South Africa and Namibia through the Southern African Power Pool (SAPP). With the abundance of solar radiation and 304 days of sunshine throughout the year (9.9 hours per day in summer and 8.1 hours per day in winter), it is pertinent that Botswana explore the use of solar energy and other forms of alternative energy like wind, charcoal and biofuels. So far, the use of solar energy has been limited to photovoltaic (PV) and solar thermal devices. PV is widely used in communications industry and for lighting of schools and clinics. On the hand solar thermal devices tend to be restricted to water heating in the residential sector. The major stakeholder is government and parastatal organisations.

Botswana needs to look to other strategies towards reducing energy consumption. One of the major energy consumption sectors is buildings and the residential sector of Botswana rates at 90% of the electrical connections per year[71]. There is a lot of energy that is consumed by the construction sector and the daily household functions. The design of housing can go a long way towards reduction of energy demand. Passive solar architecture

[70] Botswana National Atlas, 2001.

[71] Botswana Power Corporation Annual Report 2004.

has huge potential in Botswana, due to large variation in diurnal temperatures of up to 20deg C.[72]

[72] Botswana National Atlas, 2001.

APPENDIX 2

USER QUESTIONNAIRE

Please help the researcher to fill the following questionnaire for Masters Architecture Thesis. The researcher will ask questions and fill the form for you.

How the Questionnaire form is filled: There are 30 questions presented in a tabular form.

Some questions need a simple answer Yes/No.

For others, fill the required data e.g. Plot no.

USER QUESTIONNAIRE									
PROJECT:		An approach towards Sustainable, Energy-efficient Low Cost Housing with particular reference to Botswana							
1. Date	2. Plot	3. Name of person interviewed	4. Owner/ Renting	5. House Type	6. Approx. Area of Plot (m2)	7. Approx. Area of House (m2)	8. No. of rooms	9. No. of bedrooms	
		10. No. of people & families in plot	11. Bachelor/ single parent/family	12. Water borne toilet/ Pit latrine	13. Age of building	14. State of Building	15. Fenced yard?	16. Water in yard?	
		17.Electrified?	18. Type of electrical appliances	19. Roof material	20. Wall material	21. Ceiling?	22. Window location, no. & type	23. Door location	
		24. Plot & house orientation?	25. House too hot in summer?	26. House too cold in winter?	27. Type of cooking fuel	28. Type of heating/cooling fuel	29. Type of water heating fuel	30. Amount paid for electricity (P)/month	

APPENDIX 3
STAKEHOLDER INTERVIEW QUESTIONS

QUESTIONNAIRE
STAKEHOLER INTERVIEWS

For Masters Thesis in Architecture
Thesis Title: An approach towards Sustainable, Resource-efficient Low Cost Housing with particular reference to Botswana

Name of interviewee:
Department or Company:
Name of Interviewer:
Date:

I am here to conduct a survey towards integration of sustainability and energy efficiency in urban low cost housing of Botswana. The survey is part of my research thesis. It forms part of the situational analysis in the form of data collection will be carried out for the area of Gaborone West Phase 1, including a strip of the area north-south of the Goodwill Shopping Mall centred on Ntimbale road between the Western by-pass road and Rebalance road (refer to attached map).
Your organization has been selected as a stakeholder, acknowledging your role in housing construction and associated areas. The purpose of this questionnaire is basically to get feedback from the stakeholders about planning, design, energy and energy efficiency aspects in low cost houses. The reason for the interviews is for interaction, sharing of information and ideas and gathering of data.
I therefore would like to have a brief discussion with you in relation to these issues and I assure you that the information you provide here is solely needed for this project. The final write up of the thesis can be available to you if necessary.
Thank you.

STAKEHOLDER QUESTIONNAIRE

No.	**Question**	**Response**
1.	What is your job title?	
2.	How is your job related to housing or construction?	
3.	Are you familiar with the selected site for the project?	i. Yes ii. No
4.	Are you familiar with the concept of: a) sustainability in building design b) energy efficient in buildings	 a) i. Yes ii. No b) i. Yes ii. No
5.	If Yes, To what extent is the low cost housing sector of Gaborone: a) sustainable b) energy efficient	 a) i. above 50% ii. below 50% a) i. above 50% ii. below 50%
6.	Are you familiar with the concept of indoor thermal comfort?	a) Yes b) No
7.	If Yes do you believe it is necessary for residential housing?	a) Yes b) No
8.	Place the following household uses of energy in terms of priority in low cost housing. (On a scale of 1 to 5, Circle the position of each category)	a) cooking (1, 2, 3, 4, 5) b) lights (1, 2, 3, 4, 5) c) water heating (1, 2, 3, 4, 5) d) space heating/cooling (1, 2, 3, 4, 5) e) equipment & appliances (1, 2, 3, 4, 5)
9.	If you are a building designer, how often do you design low cost housing?	a) rarely b) often c) regularly
10.	What percentage of your design work is for:	a) SHHA b) BHC c) Institutional d) Private
11.	To what degree do you consider; sustainability in your work energy efficiency in your work	a) i. All the time ii. Sometimes iii. Never b) i. All the time ii. Sometimes iii. Never
12.	What determines the integration of sustainability or energy efficiency in your design?	a) client request b) company policy c) cost d) time

13.	Please rate the performance of the 2 low cost houses:	a) traditional house (1, 2, 3 4, 5) b) conventional house (1, 2, 3 4, 5)
14.	In current building sector what factors influence choice in the: a) Location of site? b) Type of low cost house? c) Type of construction materials? d) Building Technology used? e) Equipment used in the building? f) Appliance used by the user?	Please answer briefly. a) b) c) d) e) f)
15.	List (3) barriers to sustainable, energy efficient LC House, in terms of Policy & legislation, Planning, Design, Construction materials, technology and techniques, Equipment, lights and appliances.	a) b) c)
16.	List (3) interventions, in terms of Policy & legislation, Planning, Design, Construction materials, technology and techniques, Equipment, lights and appliances.	a) b) c)
17.	List benefits of sustainable, energy-efficient construction. a) to individual households b) the nation c) the environment	 a) b) c)
18.	Out of the given list tick 3 interventions that you believe can be implemented immediately, at reasonable cost	a) Lights b) Water heating c) Insulated ceiling d) Insulated walls e) Cavity wall f) Reflective roofing sheets

ADDITIONAL COMMENTS:……………………………………………………………..
…………………………………………………………………………………………
…………………………………………………………………………………………
THANK YOU for your kind assistance.

APPENDIX 4
LETTER OF CONSENT

P.O Box 404407
Broadhurst

3rdAugust, 2005

The City Clerk
Gaborone City Council
Bag 0089
Gaborone

Dear Sir

RE: Request to interview for research thesis on low-cost housing

I am presently working for Botswana Technology Centre as an Architect and enrolled with the University of Pretoria for a Masters degree in Architecture. I am undertaking a thesis project on the following research the topic:-

An approach towards Sustainable, Energy-efficient Low Cost Housing with particular reference to Botswana
As part of my research I intend to carry out a situational analysis in the form of data-collection of a chosen area of Gaborone West phase 1, including a strip of the area to the North South of the Goodwill shopping mall centred on Ntimbale road between Western by-pass road and Lebatlane road. (Please refer to the map attached).

You have been selected as a stakeholder acknowledging your role in housing related issues. I am requesting to talk to your staff in the Architecture, Planning and SHAA sections on this issue. The research material will be in good taste. As such, the final thesis write up can be availed to you if necessary.

Yours faithfully,

Busisiwe Elizabeth Sianga (Mothibi)

APPENDIX 5

ENERGY CONTENT OF COMMON MATERIALS

Material		Energy (KJ per kg)
metal	Steel	20
	Recycled steel	3.5 – 5.5
	Aluminum by hydroelectricity	75
	Aluminum by coal fired power	167
	Aluminum recycled	4.7
	Zinc	46 - 52
plastics	Polythene	138
	Polypropylene	145
	Polyvinyl chloride (PVC)	103
	Polystyrene	45
other	Cement	13
	Glass	14 – 18
	Tiles	4
	Clay bricks	4
	Ceramic minerals e.g. stone, gravel	2 – 4
	Wood, bamboo, cork	2 – 8
	Wood composites e.g. particle boards	6 - 12
	Natural rubber, unfilled	5 - 6
	Cotton, hemp, silk, wool	4 - 10

Source: The Eco Design Handbook. (2002)

APPENDIX 6

CHECKLIST FOR MATERIALS

Material attribute	Low environmental impact	High environmental impact
Resource availability	Renewable/abundant	Non-renewable/rare
Distance to source (transport energy)	Near	Far
Embodied energy within the material (extraction to production)	Low	High
Recycled fraction	High	Low
Production of emissions by material to environment	Zero/low	High
Production of waste	Zero/low	High
Production of toxins	Zero/low	High
Recyclability/reusability	High	Low
End of life waste	Zero/low	High
Cyclicity (ease of recycling)	High	Low

Source: The Eco Design Handbook (2002)

APPENDIX 7
USEFUL ENERGY INFORMATION

Solar energy source	Brief description
1. Photovoltaic (PV)	PV converts solar energy into electricity PV electricity is currently expensive: costs 0.3 to 1, 50 US dollars per kWh (equivalent to 3 to 15 BWP) - hence generation capacity low, e.g. South Africa approx. 8MW and international approx. 550MW
2. Solar thermal techniques	It involves the heating of fluids (using parabolic reflectors) to high temperatures. The heat produced is used to drive steam engines Advantages It takes up 33% less space than coal-fired power station Its plants can be located in unproductive areas such as deserts Its Solar water heaters (SWH) have huge role and can compete easily with gas & electricity ones
3. Solar cookers	They are an effective source of energy, however they are inconvenient to use.
4. Solar passive techniques	The technique uses the sun's heat to warm the building and keep the sun out for cooling. This is achieved through materials and construction. It is employed in the design of various types of buildings including residential, commercial, office and institutional.
5. Wind energy	It is one of the fastest growing renewable energy sources globally. It has a capacity of 14 000 MW providing more than 24 million MWh per year. Wind alone can meet 10% of the world's energy demand by 2020. Presently wind generation costs 0.045 US dollars per kWh.
6. Hydropower	It is a process of electricity generation by running water through turbines. Large scale generation (i.e. greater than 100MW) is a problem due to environmental and social constraints that are experienced in construction and maintenance of large dams. However, small scale is achievable. Approximately 20% of the world's electricity produced by hydropower.
7. Biomass	It provides 16% of the world's energy (wood, animal dung & agric. waste) to date, with 50% of the world's population relying on it for energy. More than 2 million of the digestors in India and about 200 000 plants are installed per year. It needs to be harvested in a sustainable way to be a renewable energy. Biogas production through decomposition of biomass or

	sewage: - leads to reduced use of wood as a fuel and subsequently, improved air quality & no trips to collect wood. - is used for cooking and lighting - some of the byproducts (manure and sewer) are used as top quality fertilizer
Solar energy source	Brief description
8. Landfill gas	Methane-driven power stations are growing in numbers and the technology is developing. In many countries methane capture from landfills is a legal requirement because of methane's greenhouse effect. The cost of this form of electricity generation is 0.03 US dollars per kWh.
9. Waste to energy	Burning of waste and the use of this energy for heating and powering electricity power stations. It has become an integral part of waste and energy management in some developed countries. - However, extremely high temperatures are needed for good efficiency and low air pollution.
10. Geothermal energy	It uses heat from the earth's core Currently it provides 7000 MW of power in 20 countries and has a global potential of 80 000MW
11. Fuel cells	These are electrochemical devices that combine hydrogen and oxygen to produce water thereby releasing energy. They can be used to replace batteries as a means of storing energy (in the form of compressed hydrogen and oxygen cylinders) from sources that are not constant such as wind and solar. - The motor industry is investing a lot of money in the development of this technology.