IMPLEMENTATION OF GREEN MEASURES FOR SUSTAINABLE LOW-INCOME HOUSING IN DEVELOPING COUNTRIES. GUIDELINES FOR THE DESIGN OF NEW SETTLEMENTS IN THE SOUTH AFRICAN CONTEXT.

By

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As the candidate's Supervisor I agree to the submission of this thesis:
Name: Prof. Cristina Trois
Date: 14/Jan/2014

Signed Cristina Trois

I Barbara Murru declare that

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DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis (include publications in preparation, submitted, *in press* and published and give details of the contributions of each author to the experimental work and writing of each publication)

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DEDICATION

To my parents that have always supported me in this incredible South African adventure.

ABSTRACT

In South Africa, about 15,3% of the households were living in 2011 in formal state-subsidised low-income houses (houses for households with income lower than R 3500 - about $ 350 - per month), whereas 12,1% were living in informal dwellings. The sustainable development of low-income housing is therefore one of the main challenges for developing countries addressing the green Agenda as South Africa, especially considering the quality of life of inhabitants and the complex socio-economic implications. Furthermore, the energy consumption patterns of low income households have emerged as one of the most important factors influencing the national electricity demand, as marked by the National Housing Code of 2009.

The complex social and environmental issues related to the living conditions of low-income communities need to be addressed with an integrated approach to the design of the settlements. Rethinking and greening the low-income housing design principles firstly represent an opportunity to strive social inequity and improve the quality of life of households.

The rationale of this study is to investigate how a strategic bottom-up approach and multi-scale low-cost green measures, implemented in the design process of South African low-cost housing, can potentially achieve environmental and social sustainability targets with affordable solutions.

The dissertation analysed a representative case study of a low-cost housing development in the KwaZulu-Natal Province. The research adopted a bottom-up approach combining participatory methods through a survey and interviews with the local community, and a scenario analysis investigating design alternatives and multi-scale green strategies (i.e. alternative building typologies, densification, passive design strategies). The proposed scenario evaluated the potential benefits of the green implementation, through qualitative and quantitative assessments based on sustainability indicators as environmental and energy impacts, social implications, safety and cost effectiveness, supported also by experimental methods using dynamic building energy modelling.

The study promoted an integrated and holistic research and design approach to foster the sustainability in low-cost housing development. The outcome of this integrated bottom-up approach defined a framework of good criteria and methods

for the design process, which can be intended as a guideline to effectively implement green measures and reach sustainability targets for low-cost settlements.

KEYWORDS: Low-income housing, Developing countries, Green building design, Low-cost technologies, Passive design strategies

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ABBREVIATION AND ACRONYMS

AML Association of Mortgage Lenders

BNG Breaking New Ground

ANC African National Congress Government

CSIR Council for Scientific and Industrial Research

DGCIS Department of Government Communication and Information System of South Africa

DHS Department of Human Settlements of South Africa

DOH Department of Housing of South Africa

ESCAP United Nations Economic and Social Commission for Asia and the Pacific

GRSA Government of the Republic of South Africa

IDP Integrated Development Plan

MDGs Millennium Development Goals

NGO Non-Governmental Organisations

PIE Prevention on Illegal Eviction

RDP Reconstruction and Development Programme

SA South Africa

StatsSA Statistic South Africa

CHAPTER 1: INTRODUCTION

1.1. Introduction

Green housing and sustainable living conditions are primary targets of developing countries addressing the green Agenda, as South Africa, both for environmental and social reasons.

Firstly, in developing countries the residential sector is expected to have the highest growth potential especially for electricity usage, due to the current large numbers of unelectrified households (Davis, 2011). The potential particularly regards areas with increased levels of urbanisation, where there is a demand for electricity provision along with formal housing development.

In South Africa, the electricity demand of the residential sector (142.815 Terajoules) accounts for about 18% of total national electricity consumption and represents about 70% of the total housing energy consumption (DME, 2006; Milford, 2009). Moreover, the operational phase of residential buildings is responsible for approximately 45 millions of tonnes of CO_2 per year, equal to 13% of total greenhouse gas emissions of the country (Milford, 2009). Although residential consumption accounts for only 10-15% of the national energy demand, it is estimated to constitute about 75% of the national variable load during peak demand (DME, 2007). Thus, increasing the energy efficiency in the housing sector could also contribute to stabilise the power grid and reduce the dependence from fossil resources and imported energy.

Furthermore, in developing countries as South Africa the sustainable development of housing plays a key role for socio-economic implications, especially considering the low-income housing sector (houses for households with income lower than R 3.500 - about $ 350 - per month), which constitutes the most critical part of the residential sector in the country.

The environment often created by the common low-cost housing practice caused poor living conditions, often preventing social integration and community living. Rethinking and *greening* the low-income housing design principles represent firstly an opportunity to strive social inequity and improve quality of life of people. Furthermore, low-income houses are very energy inefficient only partially due to the cost constraints: in the common practice, in fact, houses have been designed and

built without any consideration of basic green design principles, as marked by the new National Housing Code (DHS, 2009a). Also other past research

The complex environmental and social issues related to the living conditions of low-income communities need to be addressed with a holistic and integrated bottom-up approach to the design of the settlements. This approach should intend planning and architectural design as decision making and operative tools that, starting from the actual needs of the final users, are oriented to improve indoor environmental quality, health of people, stimulate social integrations, create job opportunity, reduce energy and resource consumption. The affordability of the green measures to be implemented in the South African building design common practice is also of key importance to allow an effective transition to sustainable low-income settlements also in terms of economic convenience.

1.2. Research question

With these premises, the research question that motivated the study is:

"Which guidelines and methodological framework for the design process can be defined for a green implementation in low-income state-subsidised settlements?"

1.3. Rationale

Considering the above motivation, the rationale of this study is to investigate how a strategic bottom-up approach and multi-scale low-cost green design principles, implemented from the scale of the settlement to the scale of the building and the single unit, can potentially achieve environmental and social sustainability targets for low-income subsidised settlements with economic effectiveness. The study investigated the potential benefits of optimised green implementation scenarios, oriented to improve the quality of life of communities toward a sustainable development of the low-income settlements.

The final aim is to provide a guideline and a methodological framework for the design process oriented to the implementation of green measures in the low-cost subsidised housing projects.

1.4. Aims and objectives

The research aims are summarised as follows:

- ✓ Understand criticalities and challenges that have to be addressed by the South African regulation to promote the sustainable development of low-income housing;
- ✓ Investigate the feasibility and the effectiveness of potential design alternatives and multi-scale low-cost strategies aimed at implementing green features in low-income subsidised housing projects, in terms of environmental, energy, social and economic sustainability.

The objectives of the study are the following:

- ✓ Provide a comprehensive literature review concerning national and international best practices on sustainable low-income housing
- ✓ Provide a comprehensive literature review concerning South African policies on low-income housing, particularly related to the sustainability targets
- ✓ Experiment a participatory approach to support the decision making process and the design choices
- ✓ Apply multi-scale green low-cost design strategies to a local case study of low-income housing development, assess their potential implications, compare them with the common practice and provide a fact based reasoning in terms of energy, environmental impact and cost
- ✓ Provide guidelines and a methodological framework for the design process oriented to the implementation of green measures in South African low-cost subsidised housing projects.

1.5. Research methodology

An integrated and holistic approach is essential to promote a sustainable development of the built environment. In terms of low-cost housing, several research investigated alternative planning and design strategies to adapt theories of housing to the actual needs of local communities. For example, the eThekwini Municipality's

Architecture Department developed a study of housing typologies applicable to the local context (topography, climate, technologies and finance) aimed to assist the urban housing challenge with authority, efficiency and understanding of the needs of the local communities (eThekwini Municipality, 2010). Other studies focused on the assessment of densification criteria in urban and peri-urban areas, investigating the relation between density and housing development (Zhu, 2012).

However, these criteria were often related to a top-down approach defined by designers, planners or municipalities. On the other hand, several studies and projects proved the importance of a bottom-up approach, where the involvement of the communities from the early stages of the decision making process guaranteed suitable and accepted solutions for the local communities, being based on their actual needs (JHC, 2010).

The studies on the sustainability of low-income housing in South Africa rarely considered the indoor comfort and energetic implications of alternative strategies for the design of the new settlements. A recent study conducted by WSP (2010), for example, investigated the benefits of various technologies of walls applied to the traditional detached house typology, but no other potential design alternatives in terms of building typologies or different architectural layouts were evaluated.

Based on the above considerations, this research adopted an integrated approach to the sustainability that combined the mentioned criteria through a holistic vision using theoretical methods, participative methods, scenario analyses and experimental assessments. These methods were combined to address the challenge of the implementation of green strategies in low-income housing development in South Africa.

The research initiated with a critical analysis of the available literature on the South African low-cost housing sector, its traditional design practice and related policies, regarding particularly the sustainability targets, to understand criticalities and challenges. Research studies and emblematic projects from South Africa, other developing countries and developed world were hence analysed to appreciate the approach to the topic from different perspectives, and to derive potential outcomes that could be transferred, with adequate filters, to the South African context.

Then, the study analysed a representative case study of a low-income housing development in the town of Bulwer (Ingwe Municipality, KwaZulu-Natal Province).

The research adopted a bottom-up participatory approach, based on a survey and interviews conducted with the local inhabitants of the settlement, to understand the main criticalities related to the current living conditions and the main challenges that the research had to address to promote the sustainability in low-income housing developments. This approach allowed basing the following scenario analysis and related design alternatives assessment on the actual needs of the local community and to engage inhabitants in the decision making process.

The subsequent scenario analysis regarded the investigation of a potential low-cost housing development scenario in the new residential area planned by the Urban Regeneration Plan of Bulwer. The analysis investigated, through both qualitative and quantitative approaches, design alternatives and multi-scale green low-cost strategies, assessed by sustainability indicators as environmental and energy impacts, land use, social implications, safety and cost effectiveness. The design alternatives and multi-scale strategies were based on different housing typologies, densification strategies, general layout of the settlement, passive building criteria, green low-cost design strategies.

The optimised scenario was then explored in terms of energetic implications and indoor environmental quality of the housing units. Through experimental methods using dynamic building thermal modelling, the proposed scenario was assessed to demonstrate the potential benefits in terms of energy consumption saving and improvement of the indoor comfort, compared with the common South African low-cost housing practice. The potential benefits achievable in terms of reduced environmental and energy impacts, improved indoor comfort and social implications were also supported by a preliminary cost assessment in comparison with the common practice.

Through the mentioned methodology, the study investigated if a proper integrated and holistic design approach could provide higher standards of low-income settlements and housing units, improving the quality of life of inhabitants toward sustainable living targets.

The research was conducted with the external advice of a local established Architecture firm, WalkerSmith Architects and particularly its Principal Architect Patrick Smith.

1.6. Outline of the dissertation

Based on the research steps mentioned in the previous section, the dissertation is structured into six chapters.

After this **introduction**, the **chapter two** includes the literature review, while the **chapter three** provides background information on the case study that is important to better understand the research methods adopted by the study.

Then the **chapter four** describes in detail the methodology for each phase of the research.

The **chapter five** describes and discuss the results of the various research stages, which are strictly interdependent.

Finally, **chapter six** summarises the main conclusions and provides recommendations for future research.

1.7. Flow chart of the research

The following Figure 1-1 shows the flow chart of the research dissertation.

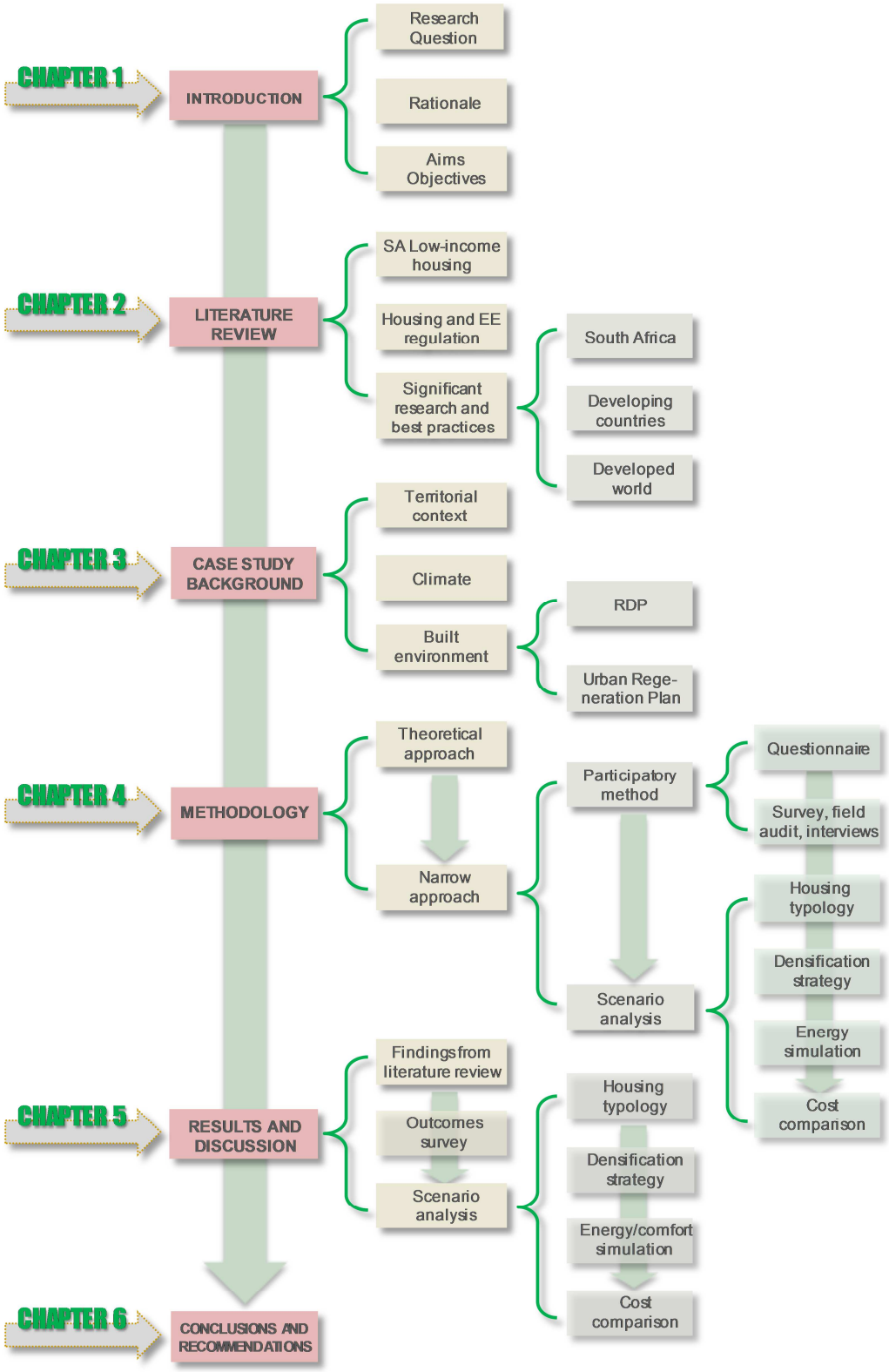


Figure 1-1: Flow chart of the research dissertation

CHAPTER 2: LOW-INCOME HOUSING IN SOUTH AFRICA: A LITERATURE REVIEW

2.1. Introduction

This chapter describes the results of a critical review of the available literature regarding low-income housing across the world, both developed and developing, and particularly in South Africa.

Firstly, an investigation of the low-income housing sector in the South African building industry was conducted in order to evaluate the issues and gaps in terms of housing demand and delivery. Hereinafter, South African housing policies and regulations were summarised, defining the main features that should be guaranteed for the development of a sustainable human settlement. The common low-income housing practice in South Africa often produced an environmental quality and living conditions that became the hotbed of social and environmental issues. On the other hand, some recent low-income housing development projects tried to address these issues and provide solutions to achieve sustainable human settlements. Criticalities and positive outcomes of several low-income housing research and projects in South Africa are hence analysed in this chapter.

The subsequent investigation analysed the state of art of low-income housing practice in the developing and developed world. Studies and projects conducted in other African countries, as well as and in Latin America and Asia were described, deriving potential inputs and lessons for South Africa. Although housing crisis damaged also the developed world, several examples of successful European affordable and social housing projects, defined valid alternatives to address sustainability targets for the low-cost housing sector. Some of these projects and research are investigated at the end of this chapter. .

2.2. The low-income housing sector in the South African context

Several national and international poverty indicators are used to define the income and living conditions of households in South Africa. The food poverty line, as well as the lower bound and upper bound poverty lines (Foster-Greer-Thorbecke poverty measure indicators), are the national poverty indicators, whereas $1,25 and

$2,50 rate per day were the international poverty line (Statistics SA, 2012a & World Bank, 2010).

The Living Condition Survey 2008-2009 stated that approximately 26,3% of the South African population was living below the food poverty line of R305 per capita per month, 36,4% was living below $ 2,50 a day and 10,7% was living below $1,25 (Statistics SA, 2012a), as shown in table 2-1.

Table 2-1: Percentage of South African population affected by key poverty indicators using various national and international poverty lines. (Source: Statistics SA, 2012a)

Poverty line	Poverty headcount (P_0)	Poverty gap (P_1)	Severity of poverty (P_2)
Food poverty line (R305) per capita per month	26,3	8,5	3,8
Lower-bound poverty line (R416) per capita per month	38,9	15,0	7,5
Upper-bound poverty line (R577) per capita per month	52,3	23,6	13,3
$1.25 (PPP) per capita per day	10,7	2,8	1,1
$2.50 (PPP) per capita per day	36,4	13,5	6,7

The same Living Condition Survey indicated the Limpopo as the poorest Province in South Africa, according to the poverty indicators of poverty headcount, poverty gap and severity of poverty (Table 2-2).

Table 2-2: Percentage of South African population affected by poverty indicators by Province. (Source: Statistics SA, 2012b)

	Food poverty line (R305)			Lower-bound poverty line (R416)			Upper-bound poverty line (R577)		
Province	P_0	P_1	P_2	P_0	P_1	P_2	P_0	P_1	P_2
Limpopo	48,5	16,6	7,8	62,1	26,9	14,4	74,3	38,8	23,6
Eastern Cape	35,7	11,8	5,3	51,0	20,4	10,4	66,1	31,1	18,0
Mpumalanga	32,1	10,9	5,1	47,6	18,7	9,7	62,5	29,1	16,7
KwaZulu-Natal	33,0	10,7	4,8	46,1	18,5	9,5	60,2	28,2	16,3
Northern Cape	26,0	7,9	3,3	42,6	14,8	7,1	58,2	24,9	13,4
Free State	24,6	7,1	2,9	42,0	14,1	6,5	57,8	24,3	12,8
North West	26,3	8,8	4,1	42,0	15,6	7,9	56,9	25,1	14,0
Western Cape	9,0	2,2	1,0	17,8	5,5	2,4	30,6	10,8	5,2
Gauteng	10,1	2,6	1,0	18,1	5,7	2,5	29,0	10,7	5,3
RSA	**26,3**	**8,5**	**3,8**	**38,9**	**15,0**	**7,5**	**52,3**	**23,6**	**13,3**

Usually in South Africa, the housing sub-markets are classified as follows:

Table 2-3: Housing Sub-markets. (Source: eThekwini, 2012)

Hosing Sub-markets	Households Income	Description
Low-income Housing	< R 3.500 per month	Informal, traditional, rental or individual ownership of serviced or un-serviced dwelling units
Affordable Housing	From R 3.500 to R 15.000 p.m.	Rental or individual ownership tenure over fully serviced dwelling units
Gap market Housing	From R 7.500 to R 15.000 p.m. (included in the affordable housing market)	Portion of affordable housing market characterised by the absence of subsidies and the thin availability of bond finance
Social Housing	From R 1.500 to R 7.500 p.m.	Subsidised rental tenure over fully serviced dwelling units
Mid-market and up-market Housing	> R 15.000 p.m.	Rental or individual ownership tenure over fully serviced dwelling units

In South Africa the residential building sector amounted in 2006 to about 12.5 million of units of which about 8.5 million are formal and about 4 million units are backyard properties, informal and squatter units, and traditional housing (Statistics SA, 2007 & BMI-BRSCU, 2007), as shown in Figure 2-1.

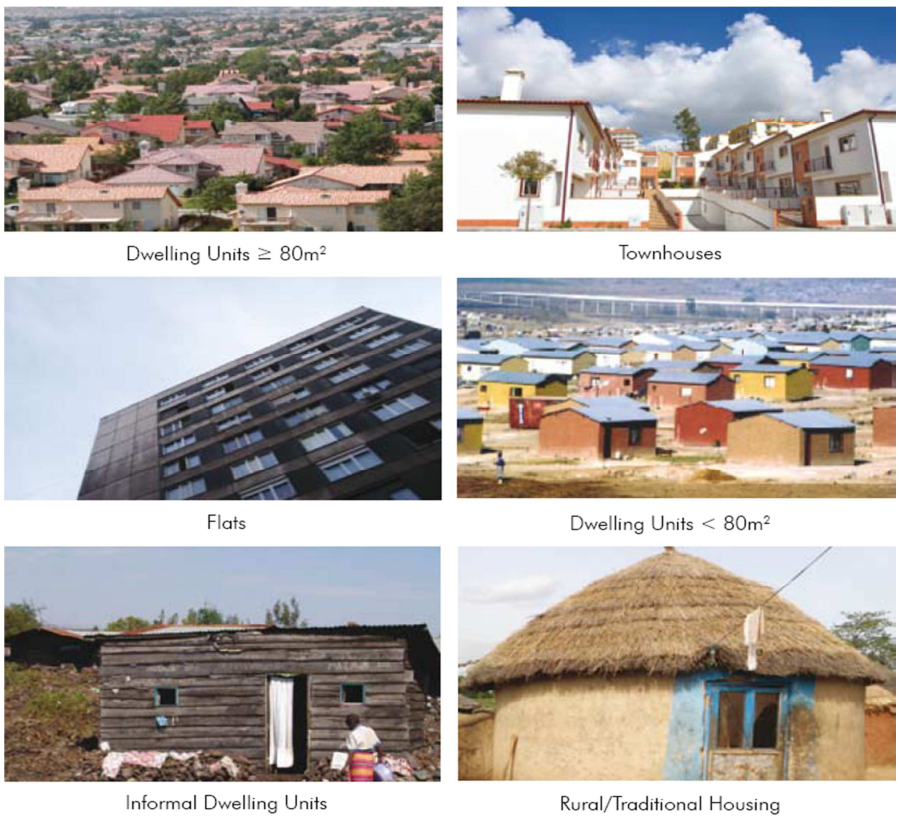


Figure 2-1: Main South African housing types. (Source: Milford, 2009)

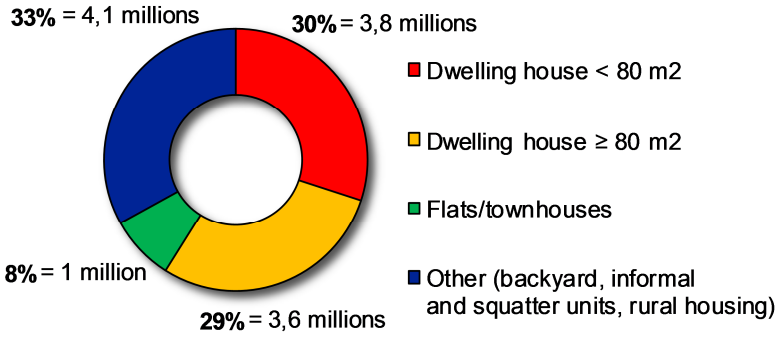


Figure 2-2: Residential building stock (number of units) in 2006. (Source: BMI-BRSCU, Statistics SA, 2007)

The information on the delivery of formal dwelling units, based on the building plans completed for the major municipalities in 2007, showed a trend towards higher density units with flats and townhouses accounting for about 27% of new floor space and about 35% of the number of new units. Figure 2-2 shows that houses lower than 80 m^2, mostly low-income housing, accounted for about 36% of the number of units delivered (Milford, 2009; Statistic SA, 2007).

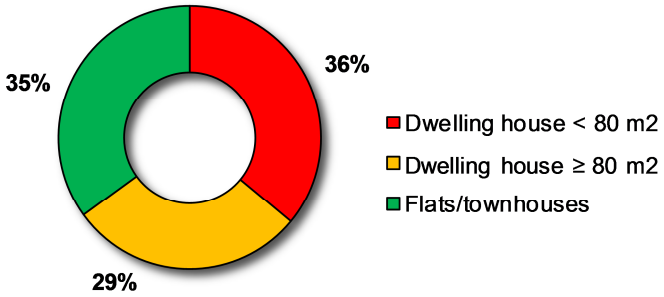


Figure 2-3: Percentage of units of formal housing delivery according to the building plans completed for the major Municipalities in 2007. (Source: Statistics SA 2007; Milford, 2009)

Following the strong National policies supporting the housing provision to low-income households, that are analysed in the following paragraph, between 1994 and June 2011 the South African Government built over 3 million homes, giving shelter to more than 13 million people (SA Government, 2013). Between 2011 and 2014, the Government of South Africa has planned to build 220.000 subsidised low-income houses per year (DGCIS, 2011) to face the current housing backlog. Low-income housing hence constitutes the most critical sector of the residential stock in the country.

The General Household Survey of South Africa 2011 showed that in 2011 about 15,3% of the South African households were living in state-subsidised low-

income houses (Statistics SA, 2012c). From 2002 to 2011, the percentage of households that received a Government-housing subsidy grew rapidly, reaching the high value in 2008, double than 2002, and pointing 9,5% in 2011 (Figure 2-4). The data were in line with the government policies, aimed to provide housing to the vulnerable groups.

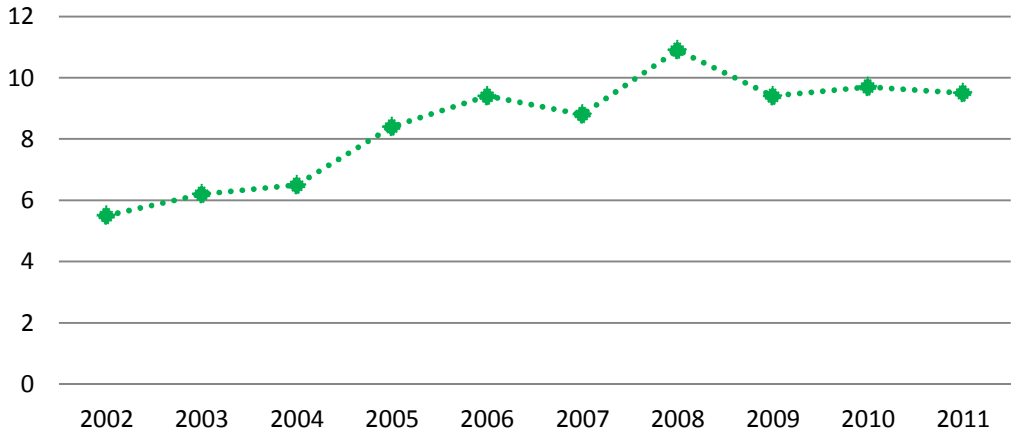


Figure 2-4: Percentage of households receiving a Government-housing subsidy. (Source: Statistics SA, 2012c)

The percentage of households living in informal units in 2011, according to the General Household Survey 2011, was 12,1%. Figure 2-5 showed that Gauteng was the Province with the largest percentage of households living in informal settlements.

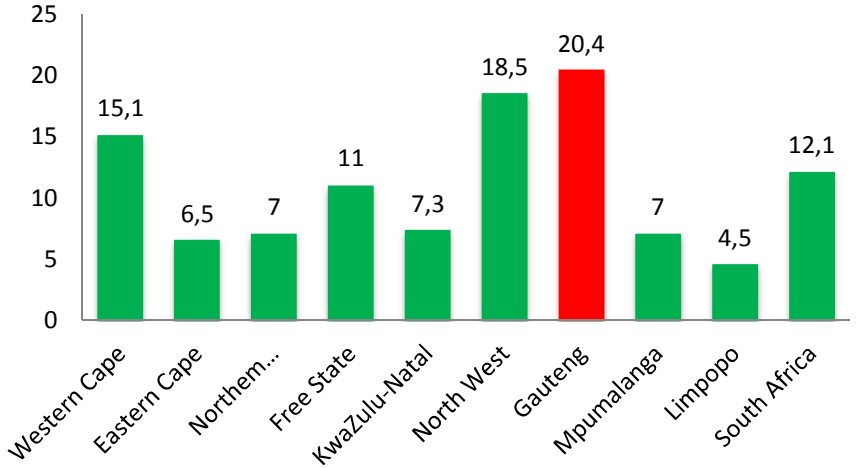


Figure 2-5: Percentage of households living in informal dwellings per province. (Source: Statistics SA, 2012c)

With regard to the access to basic services, the Living Condition Survey 2008-2009 stated that 51,8% of the poor households had access to piped water, 31,5% had access to flush toilet inside the unit or on-site and 71,2% of them were using electricity for cooking, heating or lighting (Statistics SA, 2012a). The General Household Survey of 2011 revealed data regarding the quality of the state-subsidised units, reporting that 15,5% and 16,1% of households living in those houses complained respectively weak or very weak conditions of walls and roof (Statistics SA, 2012c).

Improving the quality of low-income housing and related living conditions of households is therefore an imperative for the sustainable development of the country. The following section analyses the national regulation and policies adopted by the Government to address this topic.

2.3. Regulation on South African low-income housing: criticalities and opportunities

This sub-chapter outlines the housing policies and legislative framework in South Africa, exploring the regulatory criteria for low-income housing within the Reconstruction and Development Programme, the White Paper on Housing, the Constitution, the Housing Act, the PIE Act, the Rental Housing Act, the National Norms and Standards and the National Housing Code. Furthermore, information concerning the National Housing Subsidy Scheme (NHSS) is provided, including the generic qualifying criteria for beneficiaries wishing to access state housing subsidies.

In the last decades, the South African Government has undertaken many initiatives to improve living conditions and provide shelter to low-income communities. The housing policy in South Africa was the result of a process of intense negotiation within the National Housing Forum from 1992 to 1994 (Huchzermeyer, 2011). Since that time, numerous housing legislation and policies attested the complex nature of the housing theme in the country. The diagram of Figure 2-6 summarises the main national policies and legislation issued about housing and particularly low-income housing.

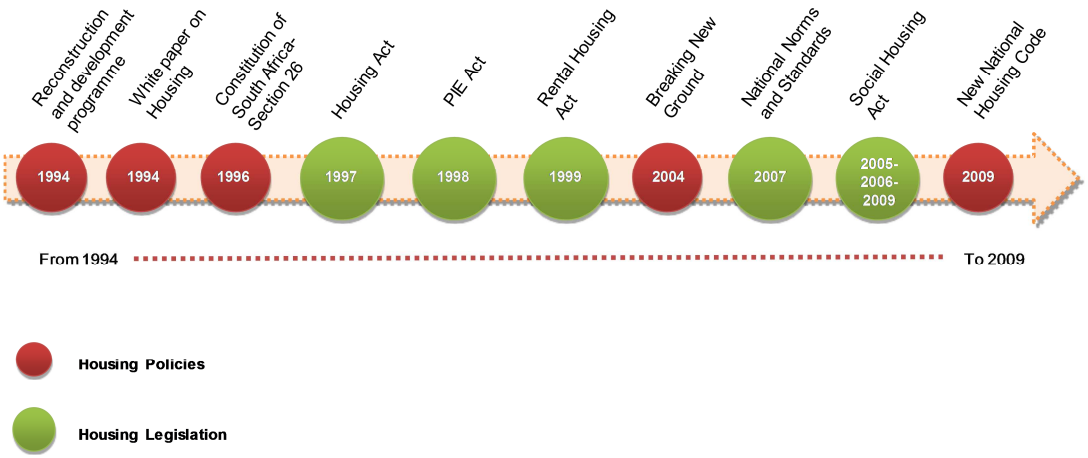


Figure 2-6: Diagram of Housing Polices and Legislation in South Africa

2.3.1. The Constitution of South Africa, the Reconstruction & Development Programme, the White Paper on Housing

The core principle of the South African Housing Policy is that housing is a basic human right, as stated in the section 26 of Chapter Two of the Constitution of South Africa, which establishes that "*everyone has the right to have access to adequate housing*" (GRSA, 1996). In addition, the same section 26 outlined the duty of the Government of implementing measures to realise the right of housing and the suppression of evictions and demolishment without an order of the court based on relevant circumstances.The declaration of the housing right refers also to the article 25(1) of the United Nation Universal Declaration of Human Right of 1948 (UN-GA, 1948).

The main key steps that changed the evolution of housing policy in South Africa toward social equity principles were the Reconstruction and Development Programme, the White Paper on Housing and the Constitution of the Republic of South Africa. The further legislative outcomes derived from and implemented the principles stated firstly in these documents.

In 1994, the African National Congress (ANC) Government of Nelson Mandela promoted the **Reconstruction and Development Programme (RDP),** a socio-economic policy framework, implemented and oriented to oversaw major advances in dealing with South Africa's most severe social problems. The framework was oriented to set programmes for rebuilding and redeveloping the country. In terms of housing, the RDP recognised the lack of housing as one of the main problems facing the country and pointed the target of one million low-cost houses state built

over five years. Government and business granted funding through a national housing bank and a national home loan. The Government also provided subsidies in order to guarantee low-income people to access financial services (ANC, 1994)

Immediately after the democratic elections in 1994, the incoming ANC government adopted **The White Paper on Housing,** based on the principle set out in the Reconstruction and Development Program. It was the first housing policy framework aimed to provide integrated settlements, in which poor households had access to adequate homes as well as basic services, such as potable water and sanitation (GRSA, 1994).

The key approach, in order to complete the target range, was the interaction between the synergistic collaboration of different participants: combined resources, community initiatives, commercial and private sector, and the state. "*The time for policy debate is now past - the time for delivery has arrived*" reported the White Paper on Housing (GRSA, 1994).

Government's initial goal was to deliver 338.000 state subsided units per annum, within a five year period, to reach the target of 1.000.000 houses in five years. In response to the large housing backlog in the country the government intensified a low-cost housing scheme (commonly referred as RDP housing from the Reconstruction and Development Programme), including housing subsidy for low-income families.

2.3.2. The National housing subsidy scheme and the RDP settlements

Tomlinson (2007) retraced the chronological development of the low income housing finance sector. Starting from 1994, the South African's government adopted a subsidy scheme directed to unlock the housing finance sector. Effectively, from 1994 South African Housing Policy had established various negotiations to face socio-economic issues such as the attraction of financiers able to invest in the black market. From 1980, because of the racial laws characterising the South African apartheid period, black people were not able to own a house in the urban area. Exploiting this fact, the low-income housing market was not financially supported by banks. Furthermore, when the black community was legally allowed to purchase housing in urban area, they were not able to manage the mortgage, because of the high increase of the interest rate and for the term of the loan (20 years).

Nevertheless, from 1994 the Department of Housing and the Association of Mortgage Lenders signed a negotiation in order to create a "stable public environment" that formalized the establishment of institutions for reducing the banks' risks (Tomlinson, 2007).

Presently, the housing financial delivery is made up of the Big Four commercial banking, smaller banks and non-bank-micro-lending. The Government Housing Subsidy promoted by the Republic of South Africa is an on-off grant offered to beneficiaries for housing purpose (DHS-KN, 2010). The grant could be paid to a seller of a house or, in case of new developments, is used to pay the construction of the unit complied with the minimum technical norms and standards. The grant is not used to pay in cash directly the beneficiaries.

To apply to the Housing Subsidy, beneficiaries have to satisfy the following qualifying criteria (DHS, 2009b):

- ✓ to be a citizen of the Republic of South Africa, or possessor of a Permanent Resident Permit;
- ✓ to be legally competent to contract;
- ✓ may not have received previous housing benefits from the Government;
- ✓ may not have owned and/or currently own a house.

Within the National Housing Scheme, there are several subsidy programmes (DHS, 2009c):

- ✓ *Integrated Residential Development Programme*: through a holistic approach, the programme provides for planning and development of integrated housing projects.
- ✓ *Enhanced People's Housing Process*: supports households inclined to build their own homes enhance their housing subsidies by building their own homes.
- ✓ *Rural subsidies:* the aim of the programme is to assist individuals living in areas referred to as "rural" areas, in which they do not have formal right in the land they occupy. This subsidy extends the benefits of the

Housing Subsidy Scheme and may be used for providing basic services, building houses or both of them.

- ✓ *Farm Resident Subsidies:* provides funding for the development of engineering services and adequate houses for farm workers and farm occupiers.
- ✓ *Institutional subsidies;* assists the non-profit Housing Institutions, like housing associations, churches, providing funding for the development of accommodation that will be rented to people from the lower-income groups. The owner of the accommodations remains the homes developers for at least four years after the construction of the houses.
- ✓ *Individual Subsidies:* This subsidy assists low-income households that wish to acquire for the first time a property. It may be used to purchase an existing house and the land in which the house is build.

Table 2-4: Example of Housing subsidy quantum for the different Housing Programmes from 11 March 2010 to 31 March 2011 for the Province of KwaZulu-Natal. (Source: DHS-KN, 2010)

Housing Subsidy Amounts	
Housing Subsidy Amounts: 11 March 2010 till 31 March 2011	
Subsidy Programme	Subsidy quantum
Integrated Residential Development Programme (IRDP) Subsidies: #	
R0 to R3 500	R55,706.00
Enhanced People's Housing Process: #	
R0 to R3 500	R55,706.00
Rural subsidies: #	
R0 to R3 500	R54,906.00
Farm Resident Subsidies: #	
R0 to R3 500	R54,650.00
Consolidation Subsidies:	
R0 to R3 500	R54,906.00
Institutional subsidies:	
R0 to R3 500	R52,427.00
Individual Subsidies:	
R0 to R3 500	R84,000.00
As an option of last resort, internal municipal engineering services may be financed from the housing subsidy. The amount available per stand is:	R22 162,00
The cost of the raw land may be financed from the annual housing funding allocation to Provincial Governments.	Market value (Currently estimated at R6 000,00 per stand)

The National Department of Human Settlements annually adjusted the subsidy quantum. Even though there is not a defined increase of the subsidy amount, every financial year the quantum is adjusted at Provincial level in order to meet the specific needs of each Province. The National Department of Human Settlements approves every year a budget for covering low-income housing costs, which consisted of indirect professional costs (Tranche 1), direct costs for a serviced stand (Tranche 2) and the amount available for the top structure (Trenche 3).

For the financial year 2013, for example, the Department of Human Settlements of the Province of KwaZulu-Natal approved the adjustment of the subsidy quantum, with effect from 6 December 2012. In 2013, a subsidy of Rands 64.666,00 (= about $ 6.550) was allocated to subsidise the construction of the top structure of the RDP unit (DHS, 2013a), traditionally based on the building typology of a detached one-storey house of about 40 m^2 in its plot, with two bedrooms, a living room and a separate toilet, as required by the new National Housing Code (DHS, 2009b).

Table 2-5: Detailed cost breakdown of a 40 m^2 subsidised house effective from 6 December 2012 for the Province of KwaZulu-Natal. (Source: DHS-KN, 2013)

Detailed cost breakdown of a 40sqm subsidised house effective from 6 December 2012		
Construction cost and subsidy amount of a 40sqm house	Earthworks (provisional)	R 916.08
	Concrete, Formwork and Reinforcement	R 4 975.52
	Brickwork	R 16 507.35
	Roof structure	R 4 332.01
	Windows	R 1 610.46
	Doors and Frames	R 1 921.68
	Finishing and Paintwork	R 2 565.25
	Electrical	R 1 275.96
	Plumbing and Toilet	R 7 660.85
	Material	**R 41 765.15**
	Labour	R 11 284.57
	Sub Total	**R 53 049.72**
	P & G	R 5 760.50
	Overheads	R 2 429.50
	Profit	R 2 125.80
	Transfer costs	R 1 000.00
	Beneficiary Administration	R 300.00
	Total	R 64 665.52
	Total Cost (Rounded Off)	**R 64 666.00**

Table 2-6: Detailed cost breakdown of a serviced stand effective from 6 December 2012 for the Province of KwaZulu-Natal. (Source: DHS-KN, 2013)

Detailed cost breakdown of a serviced stand effective from 6 December 2012	
Indirect Cost	
Professional fees	
Safety Inspector (DoL)	R 79.14
Environmental Control Officer	R 63.31
Pre-planning Studies	R 423.41
Project Management	R 868.52
Geotechnical Evaluation	R 104.24
Contour Survey	R 69.49
Land Surveying and Site Pegging	R 347.40
Land Survey examination fee	R 107.70
Town Planning	R 468.97
Civil Engineer : Services	R 1 042.21
Site Supervision : Clerk of Works - Civil	R 264.02
Social Facilitation	R 347.42
Legal Fees	R 23.78
Sub Total : Indirect Cost	**R 4 209.60**
Direct Cost	
Water Reticulation (including meter)	R 5 350.00
Sanitation Reticulation	R 6 218.48
Roads	R 3 995.11
Storm Water	R 5 784.23
Street Lighting	R 138.94
Sub Total Direct Cost	**R 21 486.76**
Total Cost of a Serviced Stand:	
Sub Total : Indirect Cost	R 4 209.60
Sub Total : Direct Cost	R 21 486.76
Total :	**R 25 696.36**
Total Cost (Rounded Off)	**R 25 696.00**

Nevertheless, cost constraints often did not allow building the internal partitions, so that houses are commonly delivered only with a separate toilet. Since 2007, the subsidy is sufficient to include a small-prepaid electricity unit for each house, including two plug points and one light unit.

Although the undeniable social achievements of RDP housing programme (i.e. provision of housing, electrification and public works, clean water, healthcare to low-income communities), the housing quality of RDP settlements has been often criticised. A research investigation in 2000 found that only thirty percent of new houses complied with building regulations. Critics also cited poor quality of units and infrastructure, noting that housing schemes were often dreary in their planning and layout, often resembling the bleak building programmes implemented by the Apartheid government during 50s and 60s years (Lodge, 2003).

Houses are also very inefficient in terms of energetic behaviour and indoor comfort, as also marked by the recent National Housing Code. This inefficient behaviour is only partially due to the cost constraints. In fact, RDP units are built without any consideration of basic green design principles and passive strategies such as orientation, shadow devices, window size to wall, thermal insulation and inertia. The model of the RDP detached unit has been often repeated indiscriminately on the land, without considering the environmental impacts and the environmental quality of the related indoor and outdoor spaces.

Figure 2-7: View of typical RDP detached units

Figure 2-8: View of a typical RDP settlement based on the detached building typology

Furthermore, it was observed (Goebel, 2007) that, although the post-apartheid South African government provided the sustainable policy framework to guarantee housing for the poorest community, it was still necessary to investigate, improve and reinforce the "social sustainability". Experts of urban settlements asserted unsustainability. Goebel stated that the reasons of the unsustainability had been observed in the neo-liberal government politics, in the enduring inequity, in the contemporary urbanization and finally in the government and the municipality. Firstly, the neo-liberal politics had expanded the marginalization and the poverty. The enduring inequity derived from the past, but it was still present in housing developing projects, where the new settlement is located on the peripheries and far from the elite areas, preventing the social integration. The third cause of unsustainability was linked to the massive urban population growth that could be translated in terms of unmanageable and rampant urban growth. The informal settlements and squatter patterns, connected to the high level of unemployment, were therefore the results of a rapid and peri-urban sprawl. Finally, the Government and Municipalities complicated bureaucracy arrested the eradication of the informal settlements and squatter patterns, connecting to the high level of unemployment, and increasing the socio-economic issues.

2.3.3. Housing Legislation

The main steps of South African housing legislative process are analysed in this sub-chapter.

The **Housing Act** of 1997 is the crucial section of housing legislation in South Africa, implementing the guidelines pointed in the 1994 White Paper on Housing. The Housing Act promoted a sustainable housing development through general principles applicable to the different regulatory levels, defining the function of Governmental, Provincial and Municipal authorities and setting the rules for financing housing development.

In the section 2(1), the Act specified the priority needs of low-income communities, which had to be recognised at national, provincial and local level. The Act also encouraged the cooperation of the whole community in order to fulfil their own housing needs. The same section promoted also education, social and economically viable communities, safe living space, integration, the prohibition of unfair discrimination and higher density of the settlements.

The Housing development is defined by the Housing Act as: "*The establishment and maintenance of habitable, stable and sustainable public and private residential environments to ensure viable households and communities in areas allowing convenient access to economic opportunities, and to health, educational and social amenities in which all citizens and permanent residents of the Republic will, on a progressive basis, have access to a permanent residential structures with secure tenure, ensuring internal and external privacy and providing adequate protection against the elements; and potable water, adequate sanitary facilities and domestic energy supply"* (GRSA, 1997a).

As mentioned above, the Act defined roles and responsibilities of the three levels of Authority, that are summarised as follows:

- **National Government**: it has to establish and encourage a sustainable national housing development through general housing policy and directives. It is a duty of the Government to monitor the implementation of the National Housing Code and the establishment of a national housing data bank and information system (considering the scarce data availability of the preceding years).
- **Provincial Government**: it has to promote and facilitate the provision of adequate housing in its Province and the allocation of the housing subsidies to the Municipalities.
- **Local Government i.e. Municipalities**: it is the implementing authority of the constitutional right to housing, through all the reasonable and necessary steps within the framework of national and provincial housing legislation and policy.

Finally, the section 10A of the Housing Act declared that a state subsidised housing may not be sold by the owner within a period of eight years from the date of acquisition (GRSA, 1997b).

The Prevention of Illegal Eviction **(PIE) Act** of 1998 is the legislation that promulgated the section 26 (3) of the Constitution that stated that "*No one may be evicted from their home, or have their home demolished, without an order of court made after considering all the relevant circumstances. No legislation may permit arbitrary evictions*" (GRSA, 1996). The Act regards all the people that, without a

proper authorization of the actual land owner, occupy land or properties (GRSA, 1998).

Apart from home ownership, the **Rental Housing Act** of 1999 defined the Government responsibility in term of rental housing property. It regulated the rental housing relationships between landlord and tenants, promoting the Government as the responsible for the growing of a stable affordable rental housing market for all the disadvantaged people, through the introduction of incentives and measures able to improve the conditions in this market sector. The above-mentioned measures might consist of rental housing subsidy programmes. Section 3 of the Act, states the relations between tenants and landlords, promoting social equity criteria in the towards tenants. To resolve the disputes between landlords and tenants, a Rental Housing Tribunals have been established, that resolve all the housing disputes, from the respect to house rules to the maintenance, reconstruction and refurbishment works. To provide information about the rights and duties of landlords and tenants, the local authority may establish a Rental Housing Information Centre (GRSA, 1999).

The Department of Human Settlements, hereafter a monitoring process, discovered the absence of Rental Housing Tribunals and the Rental Housing Information Offices in many South African Provinces. Due to this lack, in 2010 the Government formalized the Rental Housing Amendment Bill, in order to warrant the establishment in every Province of Tribunals and Offices (GRSA, 2010).

In the same year of the Rental Housing Act, the Government introduced for the first time the **National Norms and Standards**, fulfilling the terms of the Section 3 (2) (a) of the Housing Act, for which the Minister of Housing has to stipulate national policies, as norms and standards, in order to promote a sustainable housing development. With this legislation, all the minimum housing technical requirements were established. In 2007, the standards were upgraded in respect of the “Permanent Residential Structures” section that regards existing buildings and is an essential part of the National Housing Code. All the residential standards and houses constructed applying the National Housing Programme, have to respect the Norms and Standards contained in the National Housing Code. Therefore, each unit provided by the housing subsidy has to meet the following requirements (DHS, 2009a):

- ✓ Minimum gross area of 40 m^2;
- ✓ Two bedrooms;
- ✓ A separate bathroom with a toilet, a shower and a basin:
- ✓ A combined living area and kitchen with wash basin;
- ✓ If in the township there is the availability of electricity supply, a ready board electrical installation has to be guaranteed.

In addition, generally all residential properties created through National Housing Programme established with the National Housing Code have to comply at least with the following services:

Table 2-7: Minimum level of Services permitted in terms of National Norms and Standards (Source: DHS, 2009a)

TYPE OF SERVICE	MINIMUM LEVEL
Water	Single standpipe per stand (metered).
Sanitation	Ventilated Improved Pit or alternative system agreed between the community, the municipality and the Members of Executive Council
Roads	Graded or gravel paved road access to each stand. This does not necessarily require a vehicle access to each property.
Storm water	Lined open channels.
Street lighting	High mast security lighting for residential purposes where this is feasible and practicable, on condition that such street lighting is not funded from the Municipal Infrastructure Grant initiative or from other resources.

With regard to the cost of land acquisition for the housing development, the Housing Subsidy Scheme does not provide fund for land acquisition. In fact, Housing Land has to be acquired through different Programmes. The engineering services must be provided by the Municipalities and, as an option of last resort, for example if there was lack of finances, may be financed from the housing subsidy.

In order to respect the Norms and Standards and to facilitate private/public housing practitioners, in 2000 the Council for Scientific and Industrial Research (CSIR) published Guidelines for Human Settlement Planning and Design, known as “The Red Book”, that provided guideline, information and suggestions for all the actors involved in the process of housing development.

Finally, the **Social Housing Act** (2008) was first approved in 2005, then implemented in 2006 and recently the revised policy is part of the Social Housing Code included in the new National Housing Code of 2009. The above mentioned Act deals with the creation and promotion of a sustainable social-housing environment, defining the different functions of the three governmental levels (GRSA, 2008).

From the establishment of the Social Housing Regulatory Authority, the social housing institution financed by public found has been regulated. The Act statutory recognised the social housing institution, providing support. The reasons that drove to the establishment of the Social Housing Act refer to the previous housing legislation (i.e. Constitution and Housing Act), considering the need of regulated social housing and rental housing for low and medium income households unable to access the open rental housing market.

2.3.4. Recent housing policy: Breaking New Ground

Over the last decades, there was a vibrant discussion and evolution of housing policies. The debate discussed during the 1992-1994 in the National Housing Forum, which pinpointed as a crucial South African issue the lack of housing for the poor households, promoted the housing standards and provision by the State for that segment of the population.

Despite the effort of the National Housing Subsidy Scheme, the subsidised housing programme had registered relevant issues. The housing delivery was not sufficient to fulfil the demand and the housing quality was far from the standards that the forum set as a goal.

For this reason, from 2002 and 2003, a comprehensive housing policy review was necessary to undertake to resolve a number of "*unintended consequences*" related to the existing programme. These unanticipated problems included:

- ✓ peripheral residential development;
- ✓ poor quality products and settlements;
- ✓ the lack of community participation;
- ✓ the limited secondary low income housing market;

- ✓ corruption and maladministration;
- ✓ a slowdown in housing delivery;
- ✓ underspent budgets;
- ✓ limited or decreasing public sector participation;
- ✓ the increasing housing backlog;
- ✓ the continued growth of informal settlements (DH, 2004).

From the first outcomes of the programme and due to the changes in the socio-economic context in the country, a comprehensive review of the programme led thus to the approval in 2004 of the Comprehensive Plan for Sustainable Human Settlement, commonly referred to as "**Breaking New Ground**" (BNG) which represents the major amendment to the White Paper of Housing. The BNG principles should have shifted the focus towards integrating communities, providing social and economic facilities in housing projects and eradicating informal settlements.

The aim of Breaking New Ground was to develop sustainable urban settlement and quality housing, reinforcing the vision of the Department of Housing of an integrated society. The specific objectives of the new policy related to the housing development as a strong instrument for the creation of sustainable human settlements, in which poverty alleviation, job creations, economic growth and improved quality of life of poor communities could find resolution. Breaking New Ground is an integrated policy that allows citizen to become a strong participant in the development of the sustainable human settlement, rather than the simple recipient of the subsided housing, through participative approaches (DH, 2004).

Despite the good purposes, low-cost housing practice mostly continued to produce poor environmental quality and energy inefficient houses, as marked by the most recent housing codes.

2.3.5. The National Housing Code (2000, revised in 2009)

The National Housing code was issued firstly in 2000, in accordance with the Housing Act, with the aim of setting policy principles, guidelines, norms and

standards that applied to Government's various housing programmes introduced since 1994 and subsequently updated.

In 2009, the Code was revised to respond the emergent issues and needs for an actual sustainable and regulated housing development. The new National Housing Code was published in February 2010 and introduced the BNG-compliant National Housing Programmes to assist low-income households to access adequate housing in South Africa. These subsidised programmes are organized in four main categories:

- ✓ Financial Programmes;
- ✓ Incremental Housing Programmes, comprising the Integrated Residential Development Programme (IRDP) and the Informal Settlements Upgrading Programme (UISP);
- ✓ Social and Rental Housing Programmes;
- ✓ Rural Housing Programmes.

In terms of sustainability, the new **National Housing Code** marked the lack of any environmental criteria in the common low-income housing design practice and stated that energy consumption patterns of low-income households have emerged as one of the most important factors influencing the national electricity demand (DHS, 2009d). These issues referred not only to low-income housing development, but also to other factors. Particularly, due to the rapid industrialisation, South Africa has experienced a significant urbanisation more than elsewhere in Africa, often in unhealthy and industrial peri-urban areas, causing the related important post-apartheid social issues linked with policies of land redistribution, safety, health, comfort, waste management, social equity, transport, job creation, etc..

Through the National Housing Code of 2009, which aligns the low-income housing programmes to the BNG principles, the national Department of Human Settlements tried to incorporate some green measures in RDP housing units and settlements. The subsidised programmes promoted by the new National Housing Code included in fact various initiatives oriented to sustainability, focused on energy efficiency, called "sustainable energy", and water efficient use, called "sustainable water" (DHS, 2009d). Nevertheless, only some generic energy saving measures for the design of new houses were suggested, without any specific quantitative

prescriptions, risking consequently that those criteria are not implemented and verifiable.

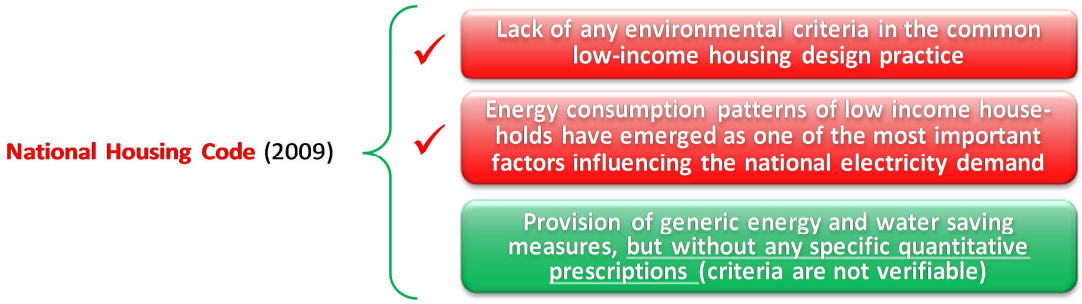


Figure 2-9: Summary of the main sustainability issues marked by the new National Housing Code and the consequent green measures provided (DHS, 2009d)

2.3.6. The Outcome 8: Sustainable human settlements and improved quality of household life

Despite all the achievements of RDP housing programme, significant levels of poverty, inequity and unemployment persisted across the country. In order to evaluate and monitor the performance of the Government, twelve outcomes addressed the main strategic priorities of South Africa, focused on the actual improvement of the quality of life of South African citizens (The Presidency, 2010a).

Each of the twelve Outcomes reflected the Governmental delivery and implementation plans for the strategic priorities from 2010 to 2014. Outcome 8, named "*Sustainable human settlements and an improved quality of household life*", aimed to achieve four performance outputs/targets through the agreements with relevant Partners, as Table 2-8 shows (The Presidency, 2010b & DHS, 2010):

Table 2-8: Four performance outputs and partners of the Outcome 8. (Source: The Presidency, 2010b and DHS, 2010)

	DELIVERY AGREEMENT PARTNERS	TARGETS
Output 1	Minister and Provincial MECs as per the IGR Act	Upgrading 400 000 units of accommodation within informal settlements
Output 2	Minister of Human Settlements and the Minister of Cooperative Governance	Improving access to basic services
Output 3	Minister of Human Settlements and the Ministers of Public Works, Public Enterprises and Rural Development and Land Reform	Facilitate the provision of 600 000 accommodation units within the gap market for people earning between R3 500 and R12 800
Output 4	The Department is working closely with its Institutions and National Treasury, as well as the banking sector	Mobilisation of well located public land for low income and affordable housing with increased densities on this land and in general

The aims of the Outcome 8 are oriented to implement crucial principles of the Section 26 of the Constitution, supporting the social development and the human dignity.

2.4. South African regulation on energy efficiency in buildings

As several developing countries, South Africa has recently implemented new policies on energy efficiency in buildings. SANS 204 ("Energy efficiency in buildings"), published firstly in 2008 in three parts, has been revised and updated in 2011, when also SANS 10400-XA ("Energy usage in buildings") was issued as part of the National Building Regulations. The new regulation came into effect in November 2011 and has attempted to align the energy standards for buildings to the current international best practices.

The new regulation is oriented to meeting the goals of the National Energy Efficiency Strategy of the Republic of South Africa aimed for the residential sector at 10% reduction by 2015 of energy use (DME, 2008).

The new standards specify the design requirements for new energy efficient buildings and services with natural environmental control and artificial ventilation or air conditioning systems. The objective is to provide guidelines for the design of new energy efficient buildings and services, in order to reduce operational energy usage in new buildings without compromising comfort and amenity.

The two policies defines specific energy requirements in terms of performance of building components (i.e. thermal resistance R-Value [m^2K/W] and time constant of composite elements CR-value [h]) and systems (HVAC, lighting, hot water), architectural design solutions (orientation, layout plan, shading systems, etc.), whole building consumption and demand. The requirements can be complied with through a rational design based on performance parameters or deemed-to-satisfy rules.

Nevertheless, these new standards do not state clearly if the requirements for residential housing are mandatory also for low-income housing. At the same time, the new policy does not define specific energy requirements for this specific housing sector, which instead would need to be addressed with a specific approach due to its singular features and critical socio-economic implications.

Therefore, currently low-income housing projects are not effectively regulated in terms of energetic behaviour. However, since 2005 the South Africa country report produced by the Department of Environmental Affairs and Tourism stated that "*the biggest benefits can be won by applying energy efficient design principles in the low-cost housing delivery. Low-cost houses have been built with no consideration to energy efficient design principles, thereby condemning already poor and suffering households with low quality, uncomfortable and "costly" houses. By designing houses in an energy efficient manner, the amount of energy required to keep the house comfortable can be reduced dramatically, thereby saving money as well as improving the air quality inside and outside the house*" (DEAT, 2005).

2.5. South African significant initiatives in low-income housing development

The low-cost housing sector in South Africa suffered the consequences of an unsustainable design approach, which has not been regulated by the National regulation.

Furthermore, many research reported an association between low-income settlement conditions and poor health outcomes. For example, the single floor detached typology in unhealthy outdoor conditions generally caused higher risk of sickness. A study undertook in an urban area in Hong Kong showed that the tubercolosis infection was more prevalent among residents on the "lower level" and decreased towards higher floors, proving how households that lived in the ground

floor, as mostly in a low-density housing developments, were most affected by TB (Lowa C-T *et al.*, 2013).

In South Africa, there is a link between overcrowding and respiratory diseases and between overcrowding and psychological suffering. In 2010, 1080 subsidised low-cost housing people in the City of Cape Town were selected as a representative sample to investigate health of low-income households. The outcomes of the interviews demonstrated that 3.5% of the inhabitants reported tuberculosis infection (Govender T. *et al.,* 2010).

Furthermore, the dangerous levels of carbon monoxide and smoke registered in poorly ventilated South African housing where coal, wood and paraffin are typically used, increased the poor air quality and the incidence of respiratory disease (DHS, 2009e).

Finding solutions to address the health and social issues, deriving from the low quality of living environment in the low-income settlement, must be considered one of the main target of the South African Authorities. The Government produced the minimum National Technical Norms and Standards for the design and fabrication of the residential sector that must be respected for all the residential development undertaken through the finance provided by the state (DHS, 2009a). According to the Housing Act, "Housing development" is "*the habitable, stable and sustainable residential environment, in which all the residents have access to permanent residential structures, potable water, sanitary facilities and domestic energy supply"* (GRSA, 1997a). Nevertheless, South African low-income housing practice often does not comply with the main codes promoted by the Government. Innovative advancements toward a sustainable low-income housing development have been promoted by contingent initiatives that should be generalised and moreover implemented at the larger scales of Provincial and Governmental level.

In the last years, several projects and research addressed in fact the challenge of sustainable low-income settlements in South Africa. In some cases, the results showed new potential solutions for a sustainable low-income housing design in the local context.

For example, Eicker (2008) stated that in Cape Town three different initiatives seemed to address the issues common to government–subsidised housing while exploring the possibility of sustainable and appropriate design. One of these projects

was the 10x10 project in Freedom Park, an informal suburb in Cape Town. The Design Indaba 10x10 Low-Cost Housing Project launched a competition, in which ten architectural teams promoted challenging projects, with the common general objective to develop alternative affordable solutions in terms of housing.

MMNLuyanda Mpahlwa architects promoted the first qualified project, a two-story timber frame and sandbag infill row houses block (Figure 2-10), designed and built with the successful community's involvement. The idea was to utilise the design stage to come up with more interesting and attractive solutions in which the sustainable design was encouraged. (Design Indaba, 2008)

Figure 2-10: Views of the 10x10 housing project in Freedom Park. (Source: Design Indaba, 2008)

Another South African best practice was the Sakhasonke Village, an extraordinary example of medium density multi-storey development. Far 5 km from the Central Business District of the Nelson Mandela Bay, this best practice won ambitious awards such as the Top National Housing Project in 2006 (Roux, 2011).

Built in the former Walmer area of about 45,000 square meters, 337 houses replaced the previous 126 promoting a medium density. The households that previously lived in the close informal settlement of Gqebere, were allocated in the new housing development. The area of the settlement, closer to the workplace for most of the inhabitants, represented at the same time the opportunity to reduce costs in terms of transportations and to improve the interactions between the residents of the settlements and the city, favouring the social integration of the community.

Designed by Lance Del Monte, the fully government-subsidised housing project focused on densification and community concepts. In fact, the two-storey cubic block, symmetrically placed on the site, created a safe atmosphere, in which

the higher level of surveillance from the double storey building guaranteed a secure environment (Kotze, 2007). The aim of the project was to bring the community inside the design, trying to resolve issues and create a safe sense of place (Roux, 2011).

Figure 2-11: Sakhasonke Village. (Source: Impulelelo Municipality, 2006)

Other projects, on the other hand, failed in achieving the planned objectives. For example, the Netreg semi-detached unit project of 2003, scarcely contributed to the consolidation of the fragmented structure of the area. The project enlarged an enclave settlement that had one single access and was surrounded by high-speed highways. This feature gave to Netreg the aspect of a gated community (Lizarralde & Massyn, 2008).

Another emblematic unsuccessful project was the RDP settlement of Braamfischerville, (Figure 2-12) initiated in 1996 in Soweto, south of Johannesburg. In 2002, two more phases were added, building housing units with similar structure to the two earlier phases. These housing development projects would have included the basic services and amenities, but six years later than the second development phase of this settlement, many of the services as running water, sewerage and electricity were still absent (Moolla *et al.*, 2011).

Figure 2-12: The RDP settlement at Braamfischerville. (Source: IOL, 2012)

Other examples, like the Cato Manor retrofit project in Durban (GBC SA, 2012), demonstrated that few strategic green retrofit interventions implemented to existing low-income settlements could achieve environmental targets and improve the quality of life of people. Nevertheless, several green strategies were already compromised in the existing settlements due to the unsustainable design practice of the past, and could not be "fixed" with a retrofit intervention. Figure 2-13 shows an internal view of an implemented unit in the Cato Manor settlement and a team of inhabitants involved in the work related to retrofit intervention.

Figure 2-13: Cato Manor retrofit project in Durban. (Source: Photo from the site visit and ClimateAction, 2011)

The analysed research studies and projects demonstrated the importance of implementing green strategies in the decision-making process and in the design practice of the new settlements, to reach targets of sustainability for the whole community with strategically planned affordable solutions from the early design stages.

2.6. Green initiatives in low-income housing from other developed countries and developed world

2.6.1. Goals for the developing countries

According to the World Bank, a developing country is *"one in which the majority lives on far less money - with far fewer basic public services - than the population in industrialized countries"*. In 2012 five billion of the world's six billion people lived in developing countries, in which per capita incomes are usually under $ 2 per day, with a significant portion of the population living in extreme poverty (under $1.25 per day) (World Bank, 2012a).

The UN Statistic Division indicated five developing regions around the world: Africa, the Americas (Northern American excluded), Caribbean, Central America, South America, Asia (Japan excluded), Oceania (Australia and New Zealand excluded) (United Nation Statistic Division, 2013).

Furthermore, the economies of the world were classified in Gross National Income (GNI) per capita, dividing the geographic regions from low-income to high-income economies (World Bank, 2013a). Figure 2-14 shows the Gross National Income per Capita, expressed in international dollar, across the world between 2009 and 2013 (World Bank, 2013b).

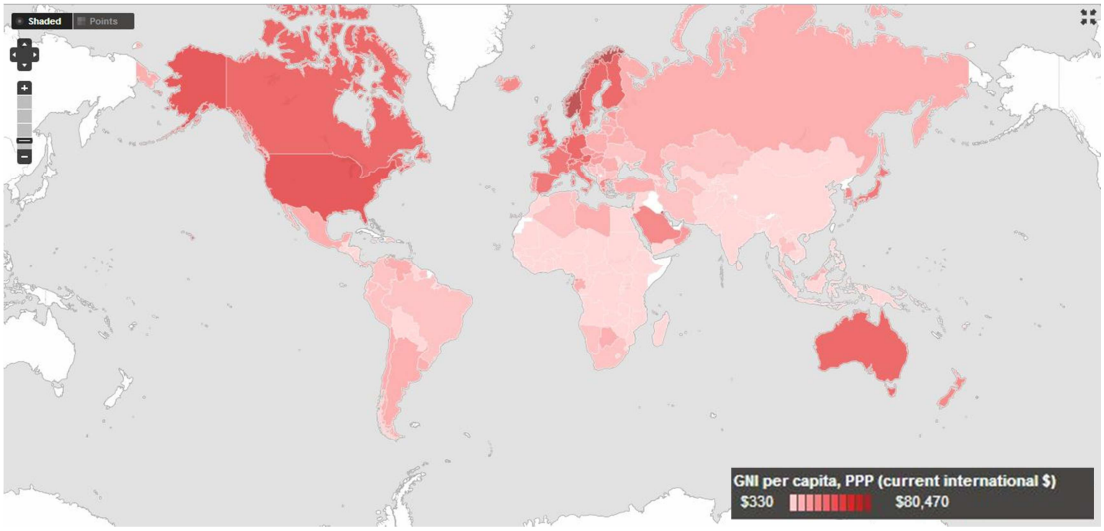


Figure 2-14: Gross National Income per Capita, expressed in international dollar, across the world between 2009 and 2013. (Source: World Bank, 2013b)

Most developing countries experienced large migration of people from rural to urban areas (Shackleton, *et al*., 2013). The necessity of job opportunities, profitable and respectable future, motivated the exodus (FAO, 2006), in which many migrants ended up in low-cost or informal areas and slums (Shackleton *et al*., 2013). Living close to the income-earning opportunities of the cities was indeed the way for the low-income households to minimize the cost to reach the workplace. This process caused the proliferation of low-income settlements surrounding the cities.

For all these reasons, lower-income communities occupied dangerous or inappropriate lands that were not used for higher purposes and should not have been occupied due to flooding or land sliding nature of the site. At the border of the cities, the lands were more accessible, but far from the working-place and the infrastructure networks (Bartone *et al*., 1994).

Urban poor settlements present similar general characteristics in all the developing countries, despite different size and shape. According to the definition explained from UN-HABITAT, the slums are urban areas in which the housing quality condition as access to water, plenty living area, sanitation and safety were absent. High density of population and houses localised in the peripheries or undevelopable land characterized the slums. Its resident showed poverty and exclusion. Because of the poverty, these communities were deeply overpowered (UN-HABITAT, 2006). On the other hand, informal settlements are illegal housing settlements characterized by poor quality.

Furthermore, the bad governments, corruption, unsuitable regulations and inappropriate governments, were indeed the causes of the slums' proliferation. (Urban Upgrading, 2001)

In order to reduce the extreme poverty, during the Millennium Summit in September 2000, the 198 world leaders adopted the UN Millennium Declaration, establishing a global partnership and to set up the Millennium Development Goals, a series of targets with a deadline in 2015 (United Nation, 2000).

The targets promoted by the Millennium Development Goals were the following (General Assembly, 2000):

- ✓ Goal 1: Eradicate Extreme Hunger and Poverty;
- ✓ Goal 2: Achieve Universal Primary Education;

- ✓ Goal 3: Promote Gender Equality and Empower Women;
- ✓ Goal 4: Reduce Child Mortality;
- ✓ Goal 5: Improve Maternal Health;
- ✓ Goal 6: Combat HIV/AIDS, Malaria and other diseases;
- ✓ Goal 7: Ensure Environmental Sustainability;
- ✓ Goal 8: Develop a Global Partnership for Development.

Figure 2-15: Millennium development goals. Source: United Nation Development Programme, 2013

The Millennium Development Goals (MDGs) promoted education, environmental sustainability and equality, to contrast the extreme poverty in a holistic approach. The purpose of the target 11 of the Goal 7, in particular, was to achieve a significant improvement of living conditions of at least 100 million slum dwellers by 2020, recognising the necessity to improve resources for affordable housing and related infrastructure (General Assembly, 2000).

The whole world has been working in the direction to achieve many of the Goals but unfortunately, the progresses are not uniform across the counties.

Sub-Saharan Africa, Asia and Latin America were the regions in which the instability and the Goals compliance has been really urgent. Sub-Saharan Africa represented the core of food insecurity, extreme poverty, maternal mortality as well as people living in very poor conditions in slums. Asia has still counted people remained in poverty conditions in spite of the economic progression. Latin America revealed persistent inequalities and slow progress in the achievement of some Goals (United Nation Development Programme, 2013).

2.6.1.1. Low-income housing in other African nations

In 2008, the United Nation-HABITAT drew up an important report (*Housing the poor in African Cities*) to provide guidance to the issues related to the urban

transition in Africa. According to the report, in 2008 only 39% of the African population lived in cities, making Africa the least urbanised region in the world (UN-HABITAT, 2008a)

Over the past half decades, Africa showed an economic growth not equally distributed in all the states. Heavy migrations from the rural areas to the cities caused an unexpected suburban sprawl. Although in the recent years the cities' growth was the result of a normal progress, in the past the urbanisation in the African cities become indeed a poverty driven process. The outcomes were inevitable: massive and uncontrolled peripheries dominated by informal settlements and irregular spatial development. Low-income communities lived far from the job opportunity, segregated in miserable settlement, without any access to adequate housing facilities as water, electricity and sanitation. (UN-HABITAT, 2008b)

In Africa, several nations addressed low-income housing challenges, trying methods to improve the living environment and to provide adequate housing for the communities.

While in the developed world housing for each income range seemed to be a right as well as the most produced standard low-income units were delivered from the Governments, in the third world, as Nigeria, the situation is often different (J. Jaiyeoba & Aklanoglu, 2012).

The World Bank classified the federal republic of Nigeria as a "low-income economy" (Gross National Income per capita of $ 1,035 or less) (World Bank, 2013c). In 2008 the population of Nigeria living on less than $1.25 a day was 43,62% (World Bank, 2013c).

In Nigeria, the low-income communities have been marginalised in terms of politics, social integration and finance. The Ogbere area was probably an emblematic case, where the low-income communities contrasted the absence of state aid or institutional help through the "social production". It referred to the initiative of building their houses from themselves, denoting the social and psychological need of identity and sense of belonging to the indigenous place (Jaiyeoba & Aklanoglu, 2012). The social built environment in this area represented a clear example of a successful process of culture and knowledge transfer, in terms of construction capacity, and of many years of failed negotiations with the

authorities. Elder people handed down the knowledge on building construction to younger people, ensuring a long tradition of self-owned houses.

Figure 2-16: Low-income housing in Ogebere, Nigeria. (Source: Jaiyeoba & Aklanoglu, 2012)

The typical low-income house in Ogeba (Figure 2.16) was a single story rectangular plot house, composed of six or eight rooms and a common space for entertainment. Toilet, bathroom and kitchen were usually located in the back of the house. The earth local material was used for the construction, sometimes diversifying the envelope materials to emphasize the sense of dignity and ownership of each property (Jaiyeoba & Aklanoglu, 2012).

Figure 2-17 illustrates the floor plan and the front elevation of the typical housing typology in Ogebe.

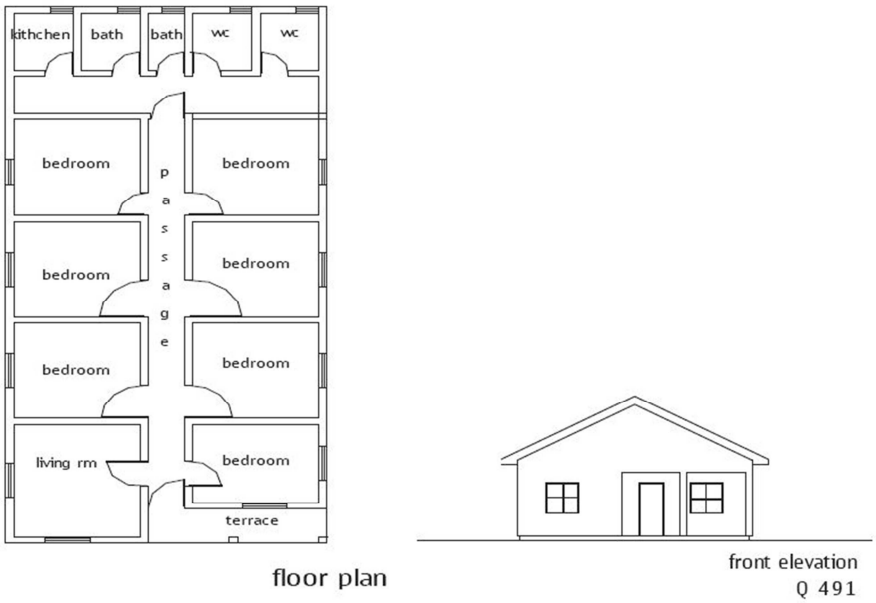


Figure 2-17: Plan and elevation of a typical house in Ogbere, Nigeria. (Source: Jaiyeoba & Aklanoglu, 2012)

While Nigeria faced the absence of housing subsidy for low-income households, other African countries adopted subsidised schemes still need to be improved to be effective.

In **Zimbabwe**, according to a study carried out by the Ministry of the Public Service, Labor and Social Welfare in 1996, at least 46% of the households in the urban area were disadvantaged members of the community in poor condition, whereas the poverty was higher in the rural areas (72%) (Kamete, 2000). The predominance of inadequate low-income houses in urban areas caused a situation in which it was necessary to adopt subsidy schemes to guarantee the housing access to low-income households, unable to afford a loan. Nevertheless, the mechanism of the subsidy scheme did not allow households to repay the house, demonstrating the unaffordability of the housing provided by the Government. About a quarter of the housing requesters could not afford the delivered houses. A revision of the housing scheme and a reduction of housing cost were therefore implemented to guarantee the affordability to the majority of the low-income population.

Other projects from Zimbabwe produced instead positive outcomes. In 1993, the Government of Zimbabwe established the Dzivareasekwa Extension (DZ Ext.), a low-income settlement located 18 km west of Harare allocating originally over 2,000 families. The houses, built with materials as brick, mortar, wood, polyethylene and metal, were semi-permanent structures. Basic services as communal toilets and boreholes for the water were located within the settlement. The settlement is located on state-owned land allocated to the Zimbabwe Homeless People's Federation in 2007 by the Government.

In January 2012, a partnership between the architect Greg Bachmayer, the Zimbabwe Federation and the NGO Dialogue on Shelter proposed new affordable housing models to promote the upgrade of the DZ Ext. settlement. This was an opportunity to develop new housing model based on the engagement of local community in the decisional and design phase, in order to provide housing schemes responding to the needs of inhabitants (Bachmayer, 2012).

Figure 2-18: 3D model of a typical streetscape of completed terraces. (Source: Bachmayer, 2012)

Another African country, Kenya**,** in the past twenty years experienced a shortage of housing in the urban and rural area because of the depressed economy. As a result, informal settlements proliferated, sharpening conflicts between landlords and occupants, especially in the low-income areas within the cities. Most of the population in Kenya lived in not adequate conditions as well as the provision of housing was far from a high standard of quality (Shitote *et al.*, 2006). Houses in the rural areas were mostly made of timber, mud and very few concrete/stone/brick constructive elements; while in the urban areas, the majority of the houses were made of concrete or stone. “Slums” also characterized spaces in the urban areas in which the housing structure was temporary and houses were made of mud or iron sheets. The restricted material choice for housing in urban areas, as well as the basic and obsolete construction technologies, incited international Non-Governmental Organisations and the National Housing Corporation to experiment the use of alternative technologies for the construction of the Pumwani high-rise housing in Nairobi. The results of the experiment revealed that it was possible to adopt pre-cast concrete technologies for the low-income housing development, adapting and speeding the construction phases. The industrial growth was also related to the experiment, considering the mass production of the majority of construction elements (Shitote *et al*., 2006).

Figure 2-19: Foundation and column erection, Pumwani, Kenya. (Source: Shitote *et al*., 2006)

Figure 2-20: Roofing, Pumwani, Kenya. (Source: Shitote *et al*, 2006)

The African research and projects analysed in this sub-chapter showed different approaches to the challenge of low-income housing. They reported successful outcomes in terms of the implementation of alternative construction technologies and housing schemes. Furthermore, these case studies demonstrated the crucial role of social responsibility of inhabitants and community engagement for the achievement of sustainability targets.

2.6.1.2. Low-income housing in Latin America and Brazil

In Latin America, as in several developing countries, the majority of population lives in informal settlement on the boundaries of the big cities.

Recent research, focused on the housing topic in Latin America, demonstrated that the cost constraints were the main factor affecting the feasibility of low-income housing interventions. In 2012, the Governments were still promoting policies regarding the basic infrastructure rather than undertaking wider programmes of sustainable development of the sensible areas in which the lower-income

communities were located. Besides, the promotion of an urban sustainable development should have been led by policies supporting resource efficient low-technologies in housing development, in order to easily implement the low-income residential sector initiatives (Sullivan & Ward, 2012).

Sullivan and Ward (2012) elaborated a framework for the local context to assess the potential implementation of different “green” and low-cost interventions for low-cost housing, demonstrating the feasibility of some measures and hence driving the local governments to adopt measures in this sense. Sustainable technologies applied to low-income settlements would in fact make them more energy efficient and sustainable, improving the quality of life of the residents as well as to benefit the environment (Winkler *et al*., 2002).

Figure 2-21: Low-income housing in Brazil. (Source: Quim Drummond)

Also in South Africa the low-income housing sector could be considered a critical field of investigation regarding the economic sustainability of low-cost technologies able to improve the behaviour of the single units and the entire settlement. Policies and incentives promoting recycle and reuse, renewable energy, collection and treatment of solid waste, reuse of greywater and rainwater should be specifically customised for the low-income housing market, as done with the solar water heating systems.

2.6.1.3. Low-income housing in Asia

According to the United Nations Economic and Social Commission for Asia and the Pacific of 2008 (ESCAP), the housing development in Asia was related to the progress of the economic sector. In fact, during the rapid economic growth, an

increasing number of poor households were evicted from their settlements to peripheral areas, far from job and economic opportunities. On the other hand, during the Asian financial crisis, evictions decreased because of the collapse of the sector of the real estate (UNESCAP, 2008).

In the past, new migrations affected most Asian cities. For example, in South Korea, between 1960s and 1970s, because of the rapid economic development, migrant workers from the rural areas crowded the cities and they ended into the peripheries. In that period the population that lived in “slums” increased from 20% to 30% (Ha, 2007).

Nowadays, the economic recovery required the responsibility of the local governments to adopt instruments in order to defend the rights of the urban poor and to achieve a significant improvement in their lives. The Virtual Policy Studio is the latest program established through the ESCAP, the Centre for Education in the Built Environment (University of Wales, Cardiff) and the Urban Management Centre (Asian Institute of Technology), with the purpose of collaborating in training and learning with regard to housing for poor communities (UNESCAP, 2008).

Another critical issue in the Asian cities was the land scarcity. Zhu (2012) observed that in Vietnam in the 1990’s about two-third of the housing were slums and from 1990 to 2009 the population increased by 30%. The Government did not have budgets for the construction of housing, then the housing policies consisted of the delivery of lands (based on socialist principle) to the households in order to build houses themselves. Because of this, the country incremented the low-density development, generating a resulting land scarcity that has to be resolved through higher scheme of densification.

Contrary to Vietnam, the Malaysian Government provided by the years to allocate low-income households in low-cost residences, both in the urban than in the rural areas, through housing developing programmes (Hashim *et al*., 2012). The performance of one of these low-income housing programme was evaluated through an audit survey. In Selangor, the most populated state in Malaysia, a study was conducted on a low-cost public housing project, via interviews and feedback to understand the perception and issues from residents, non-residents and management staff. The results showed that the incorrect and unsustainable management of the block mostly affected the negative performance of the building. This study demonstrated that the engagement of all the people involved in the

housing process through surveys and field audit is an important tool to check the outcome of low-income housing programmes and the actual satisfaction of final users, providing inputs for future implementation or avoiding the same negative outputs in future similar projects.

The need to address solid and affordable solutions for low-income housing was one of the main challenges in the developing world. The literature showed issues in different context and promoted useful solutions that could be transferred with adequate filters to the South African context. The eradication of the low-density development, the necessity of policies for the legal assistance of housing and the importance of the engagement of final users represent measures that the developing world, including South Africa, should implement.

2.6.2. Affordable housing in the developed world

In the developed world as Europe, housing access is currently becoming an issue for an increased number of households, especially after the recent economic crisis.

The most vibrant and proactive testing ground for state-subsided housing has been the social housing. In this field, the constraints of construction costs required high standard and quality of sustainable design, especially focused on passive building design based on low-cost strategies aimed to reach sustainability targets.

The included references of emblematic research and projects of social housing are thus valuable to gather important findings and learning that could be transferred also to the low-income housing sector in South Africa

The following sub-chapters illustrate case studies of social housing across the developed world. Experiences from Europe, Canada, Australia denoted the importance to provide housing to the less advantaged communities, preserving dignity and allocating them within the cities.

2.6.2.1. European experiences in social-housing

The first analysed case study regarded a successful social-housing residence in Paris, France. In 2004, the controversial French architect Edouard François designed the Flower Tower, committed by the *Opac the Paris*. The project consisted

in a vertical building, characterised by a green bamboo screen with the double function of creating a sense of privacy for the inhabitants of the block, ensuring a vertical continuity of the green environment created by the adjacent park and finally acting as a shading system during the summer season (François, 2004). Figure 2-22 illustrates some views of the building.

Figure 2-22: Views of the Flower Tower, Paris. (Source: François, 2004)

This project was a clear example of integrated development, in which the concrete block of residences was completely immersed into the green surrounding environment and close to the services useful for the community (François, 2004).

The innovation promoted by the Flower Tower revealed the need to overcome the social segregation that often characterises the low-income communities. The integration of low-income housing development programmes in urban areas could represent a challenge to favourite the social integration of these communities.

During the years 1983-1985, the famous contemporary Vienna's artist Friedensreich Hundertwasser (1928-2000) designed the Hundertwasser House, a low-income apartment's block in the city of **Vienna** in Austria. The House is the synergy of bright colours, organic forms, incorporation of natural features and interaction between nature and humans, denoting a strong individualism. Hundreds of threes inside the building and garden roofs frame a total of 52 apartments, four offices and terraces.

This case study has been considered one of the most representative low-income projects in the entire world, attracting thousands of visitors every day and

denoting how it was possible to improve the quality of the building thought artistic implementation, creating a unique sense of place.

Figure 2-23: Vienna da trovare. (Source: Hubert Kluger, 2010)

The European nation that probably above all experimented in the topic of social housing has been Spain. Particularly, the Housing Authority of Madrid (Empresa Municipal de la Vivienda y Suelo) implemented in the last year a massive programme of social housing, based on the criteria of housing quality, flexibility, sustainability, low-cost strategies, passive design principles, aesthetic quality as an feature to develop a sense of identity of residents.

Empresa Aguinaga Y Asociados Arquitectos designed in 2008 a social rental housing block in **Madrid**. The developers requested from the very beginning, according to the nature and the aim of the Municipal Programme, criteria of sustainability, economy and viability. The architects responded to the requests promoting a closed block with a large central patio, repeating the horizontal flat typology facing two directions. The internal hole referenced the great courts of the Universities in England. A centralised system managed the energy production, while the solar panels on the roof advantaged the energy supply.

Figure 2-24: Views of the social-housing case study in Madrid. (Source: Pictures from site visit and Fernandez Per *et al*., 2009)

The façade was characterized by the repetition of single modules of different colours, matched according to the works experimented by great artist Paul Klee. Window frames, as well as the entire façade, did not request special maintenance and elevated costs. (Fernandez Per *et al*., 2009)

Finally, the Town Houses in Amsterdam was an extraordinary example of urban regeneration plan. Located within an area in a continuous development, Atelier Kempte Thill in 2008 promoted a contemporary interpretation of the traditional row house, replacing the existing units with an innovative version of the terrace houses. The maximum number of units were allocated in the site. The reduced dimension of the two frontages of each unit made the units quite deep. This choice derived from client's request of cost saving: the façade in fact, being the most

expensive component of the unit, was reduced to the minimum size (Atelier Kempte Thill, 2008).

Figure 2-25: Town Houses social housing, Amsterdam. (Source: Atelier Kempte Thill, 2008)

. On the other hand, openings in the front were maximized in order to guarantee the daylight supply. Outside, an innovative concept of parking area below each unit and a terrace system covering it completed the project, promoting once again an innovative response to the complex requirements of social housing (Fernandez Per, 2009).

The European experiences in social housing promoted energy efficient social housing buildings, complying at the same with the cost constraints. These examples showed the implementation of a holistic vision of sustainability of housing for disadvantaged households, intended not only as energy and environmental awareness, but also as flexibility and adaptability of units for future needs, promotion of social integration and facilities, fostering the sense of identity of the community through innovative, functional and aesthetic high quality buildings.

2.6.2.2. United States and Australian best practices

The following studies introduce the topic of alternative construction technologies and passive building design that could reach advantages in terms of

interior thermal comfort for the inhabitants, environmental and economic sustainability of the building.

Hardin and Comella. (2007) observed that in low-income housing the approach to the climate conditions of the site necessarily implied design and construction strategies that had to be related to the local low-cost resources. In 2004, a pilot study was conducted to establish low-cost strategies in a desert low-income neighbourhood in Arizona (United States), characterised by very hot climate, in which it was required to guarantee the interior thermal comfort at least during the night. Composed of 16 houses, the Tucson low-income housing experiment tested and demonstrated the benefits of different low-cost construction methods to stabilise the interior temperature, demonstrating therefore the efficiency of thermal insulation and thermal mass. The different strategies included insulated concrete block, polystyrene panels, integrated steel framing and the environmental friendly straw bale system (Hardin and Comella, 2007).

Actually, thermal insulation and thermal mass are not the only available passive strategies for the improvement of indoor comfort. Other green strategies as orientation, form of the building, window to wall ratio, natural ventilation and conscious material choice are indeed important keys of a successful sustainable design project. Thus, from the early design stage, it is crucial to maximize the contribution from all the passive strategies, that need to be customised to the local context.

Figure 2-26: Overviews of the Tucson low-income housing experiment. (Source: Hardin and Comella, 2007)

An excellence of green strategies implementation for social housing comes from Australia. While from 1950's to 1960s the 90% of the citizens owned their house, from 1990s Australia, as many other developed countries, experienced housing price rising in comparison to the incomes, making difficult the access to housing market. Because of this, in Sydney the number of homeless rised, as well as the number of people that decided to leave the city to settle elsewhere. In this context, two housing policies promoted by the Government have failed to provide housing for the low-income households (Yu, 2005).

Nevertheless, recently some examples tried to prove the positive outcomes of sustainable design applied to low-income people. The Lilyfield Housing Redevelopment Project in Sydney represented an Australian excellence in terms of sustainable design, validated by the Green Building Council Australia (GBCA, 2011). Designed by HBO+EMTB for Housing NSW in 2011, the project achieved the five Star Green Star-Multi Unit Residential rating, setting new standards for the development of public housing in Australia. The project site was previously occupied

by 40 apartments, which were replaced by new 88 one-bedroom, two-bedroom and three bedroom apartments, completed integrated in the urban context and respecting the character of the existing neighbourhood.

In terms of sustainable design in public housing, the project reached high level of reduction of energy consumption, adopting robust passive design strategies, in order to benefit from the interaction with local climate and reduce the operational cost. Adopting low-cost construction technologies, the project contained construction cost without compromising the apartment's energy efficiency. Concerning the Indoor Environment Quality, in all the 88 apartments there were not air-conditioned systems but they were naturally ventilated. Photovoltaic panels on the roof provided energy for all the units, while the roof elements were designed to produce hot water from the solar gain. The tilted north-roof maximized solar gain during the colder seasons and shaded the solar radiation during the hot seasons. Taking advantage of the thermal mass, solid floors were exposed to the northern direction. An under building rainwater tank provides water reused for irrigation, toilet flushing and washing machines. Communal areas developed in the project improved the sense of community between all the residents (HBO+EMTB, 2011).

Figure 2-27: Overviews of Lilyfield Housing Redevelopment Project, Sydney (2011). (Source: HBO+EMTB, 2011)

2.6.2.3. A Canadian experience

Other projects interpreted the sustainability primarily as reduction of the environmental impact and footprint of the building. In **Vancouver**, for example, the Atira Women's Resource Society realised the Imouto Container Housing project, addressed to provide housing for low-income women older than 50 years.

The housing project was realised utilising 12 recycled shipping containers in a three-storey configuration, becoming the Canada's first container social housing development. According to the not-for-profit organisation that committed the project, even though the limited budget, the priority of the designer was to make "green" the housing project, through a careful selection of materials and resources, design innovations. In terms of regulation, the project met all the National Building Codes, also exceeding the insulation and sound transference requirements stated by the code. Each unit was self-contained, composed by bathroom, kitchen and laundry.

This project was an extraordinary example of reused materials applied to the social housing (Atira Women's Resource Society, 2013).

Figure 2-28: First containers social-housing in Canada. (Source: Atira, 2013)

2.7. Challenges for the sustainable development of low-income housing in South Africa

For many years in South Africa the ideology of modernism dominated the planning and design of the settlements, often generating low standard of services and high levels of inconvenience of the built environment, in particular within the districts created for the disadvantaged members of the community (CSIR Building and Construction Technology, 2001).

Many policies came in succession, aimed to promote the integration and the mixed-use of the settlements. For example, the Urban Development Framework of 1997 promoted the physical, social and economic integration of the towns and cities, identifying the need for higher density and more compact settlements. Furthermore in 2004, the Comprehensive Plan for the Creation of Sustainable Human Settlements gave effect to important changes in terms of policy framework, switched the necessity to provide housing into the creation of sustainable human settlements (GRSA, 2004).

Although the wide range of South African policies, programmes and plans aimed to address the housing challenges, the sustainability of the built environment within the low-income settlements was not encouraged. Most settlements implemented through various subsidy schemes were built without any consideration of environmental principles. Because of this, many residential habitats were smoggy, barren wastelands, decreasing the quality of life of the residents (DHS, 2009a).

However, as observed by Castro-Lacouture *et al.* (2009), international best practices demonstrated that, through a controlled design process and materials selection method, rather than investing in high-tech solutions, it is possible to meet desired environmental goals at a lower cost. With the current best practices in green building design, it was observed (Milford, 2009) that in South Africa energy efficiency savings around 30% to 40% could be obtained in new buildings in the residential sector.

The outcomes from the available literature and the research focused on the low-income housing topic across the world suggested successful and innovative solutions.

The main principles gathered from the international best practices promote a holistic approach to low-income housing design, deriving the criteria summarised in the following sub-chapters as key strategies to address the challenge of sustainable development of low-income settlement in South Africa.

2.7.1. Integrated approach, good location and participatory development

An integrated and participatory approach represents a priority for successful outcomes of the projects.

In South Africa, low-income settlements were usually located in the peripheries of the cities and frequently they were lacking of services for the community. Therefore, critical design principles are good location, social services, transport, open spaces, entertainment places for the community, which could resolve many issues related to the social integration of the community. Simultaneously, the design approach needs to be linked to the actual needs of the inhabitants, giving them the opportunity to participate during the entire decision making process.

The integrated and participatory approach represents the reasonable and necessary step that municipalities must consider during the design phase of the settlements, in order to guarantee adequate housing for the citizens (GRSA, 1997). Some projects in the South Africa context showed the potentiality of an interdisciplinary approach that could be considered as good practice for future planning of low-income settlements.

For example, the Caar Gardens project, aimed to transform and regenerate the inner-city of Johannesburg, was one of a series of initiatives launched in 2002 by the Gauteng Provincial Government to promote the integrated development and participatory approach. The well location of the housing settlement increased the economic opportunity, the access to the transport nodes and to the social facilities. The housing development was organised into a triple bottom-line, including social, economic and environmental criteria for each unit.

The unexpected results of the project comprised positive outcome in terms of social and environmental sustainability. Furthermore, the involvement of the

residents during the decisional and construction phases guaranteed the inhabitants satisfaction.

Figure 2-29: Exterior view of the Carr Garden housing development. (Source: JHC, 2010)

On the other hand, the Stock Road project in Cape Town represented a failure in terms of low-income housing development, denoting the criticism related to the negligence towards the integrated and participatory approaches. This project was promoted by the Cape Town Community Housing Company in 1999, a private company operating in the delivery of affordable housing. Due to the nature of the involved partners, more interested in business than community satisfaction and the poor cooperation between the company and the Municipality, the needs of residents, the community participations and the design approach were not considered. The result showed unaffordable houses for the living community (Tonkin, 2008).

Finally, the education of the inhabitants are integral parts of a sustainable partecipatory process. Recent research demonstrated that the behavioural response had an impressive impact on energy consumption, especially for heating and cooling, thus great results could be achieved through a proper education stimulating behavioural adjustments in everyday life (Langevin *et al.* 2013).

2.7.2. Greening the settlement

The implementation of multi-level strategies, from the larger scale of the settlement to narrow scale of the single unit, would be considered and tested as potential approach to achieve higher standard of housing quality and living conditions for the inhabitants.

Within this perspective, communal spaces can play an important role to foster social interaction and collaboration. For example, many studies proved the benefits of community gardens, that represented part of civic agriculture and a food production system strongly linked to a community's social and economic development (Lyson, 2004). In a housing development in Baltimore, the communal garden became a place that allowed community members easy access to fresh products (Corrigan, 2011). This is even more worth for the neighbourhoods of poor communities: as observed by Furey *et al.* (2011), the presence of communal gardens could provide healthy fresh foods and alleviating the expense of households.

A very interesting South African green initiative, based in the Wits Health Consortium and the University of the Witwatersrand in Johannesburg, is the Siyakhana project, aimed to promote health both in the urban, peri-urban, and rural areas. The main project of this initiative was the Siyakhana Permaculture Food Garden that launched research, training course and consultancy services in ecological design through the promotion and distribution of local production and distribution of healthy food (Siyakhana, 2013).

Figure 2-30: Photos of the Siyakhana Permaculture Food Garden. (Source: Siyakhana, 2013)

2.7.3. Passive design and low-cost strategies

Finally, a proper sustainable design approach firstly focuses on the massive adoption of passive design strategies customised to the local context and climate. All the research and projects from the developed world adopted green design criteria that are primarily based on an intensive interaction between building components and the climatic conditions. The aim was to benefit from this interaction, controlling the indoor comfort through the modulation of the natural energy flows due to the climate as much as possible. The main passive strategies achievable in low-income housing are summarised in the Figure 2-31.

Furthermore, many passive strategies, as correct orientation, layout of habitable rooms, natural ventilation, shading systems, depend primarily on sound architectural design choices and could not necessarily require additional cost if integrated in the architectural design process and subsequent output. For example, cross ventilation, that also can provide to remove pollution, depend on the

distribution and size of openings in the opposite facings and can be forced with specific design criteria.

Figure 2-31: Summary of the main passive strategies achievable in low-income housing design

This aspect is much more relevant for the low-income housing sector, in which the cost constraints is a prerequisite and therefore low cost interventions are a priority to achieve the economic sustainability of the projects.

A climate sensitive building should therefore represent a model for the sustainable development of low-income settlement. This aim requires a new sensibility of designers from the early design stages. Low-income housing design, instead of investing in innovative high tech solutions, should promote appropriate low cost strategies that firstly foster integrated passive design principles.

2.8. Summary

The literature review addressed the topic of low-income housing in South Africa, investigating the main criticalities in the current South African legislation and practice, and deriving findings from other research studies and best practices all over the world, both developing and developed countries.

The main sustainable design principles for low-income housing, gathered from the literature, were summarised in the sub-chapter 2.7 as challenges for the sustainable development of low-income settlement in South Africa.

In the chapter 5 “Results and discussion”, a synopsis of the main findings from the literature is included as cross-comparative tables assessing legislative and design criteria.

CHAPTER 3: CASE STUDY: THE RDP SETTLEMENT IN BULWER. BACKGROUND INFORMATION

3.1. Introduction

This chapter provides introductory and background information on the case study assessed within the research. This information supports a better understanding of the research methodology, whose methods and approaches are explained in detail in the following chapter.

The case study is the RDP settlement in the town of Bulwer in the Ingwe Municipality and was selected being representative of the traditional RDP housing practice in the South African context. The settlement is in fact a low-cost housing development in a greenfield area based on the traditional detached single storey house typology.

The analysis of the case study considered the social and environmental issues produced by the traditional RDP housing practice and related to the local context that implied suitable research approaches and the subsequent proposal of sustainable design criteria. The information provided in this chapter hence allows to understand the specificity of the context and the challenges that the research had to address.

3.2. Territorial context

The town of Bulwer is located in the KwaZulu-Natal Province within the north-western portion of the Ingwe Local Municipality, along the R617 route between Donnybrook and Boston, as illustrated by the Regional Locality map (Figure 3-1).

Ingwe Local Municipality is located within the Sisonke District Municipality which is bordered by Lesotho to the west, Alfred Nzo District Municipality to the south west and uMgungundlovu District Municipality to the north east.

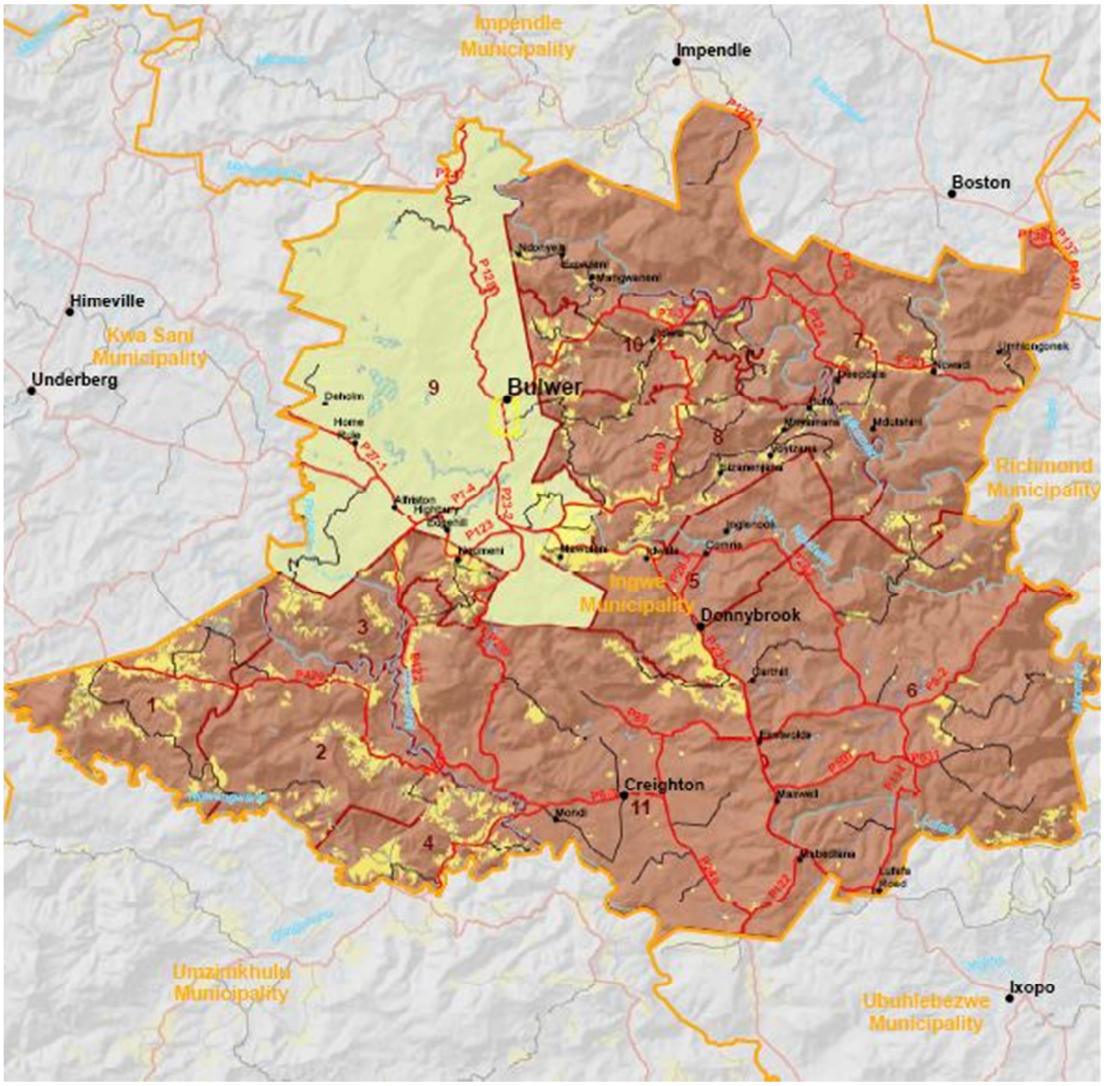


Figure 3-1: Regional Locally map. (Source: Bulwer Urban Regeneration Plan)

Ingwe Local Municipality also borders the Kwa Sani Local Municipality to the west, uMzimkulu Local Municipality to the south west, Ubuhlebezwe Local Municipality to the south east, Richmond Local Municipality to the east, Msunduzi Municipality to the north east and Impendle Local Municipality to the north.

According to the Ingwe Spatial Development Framework of 2007, Bulwer was identified as a primary node, considering that the main administrative and commercial centre was located in the town. On the other hand, the Donnybrook and Creighton Municipalities were identified as secondary nodes.

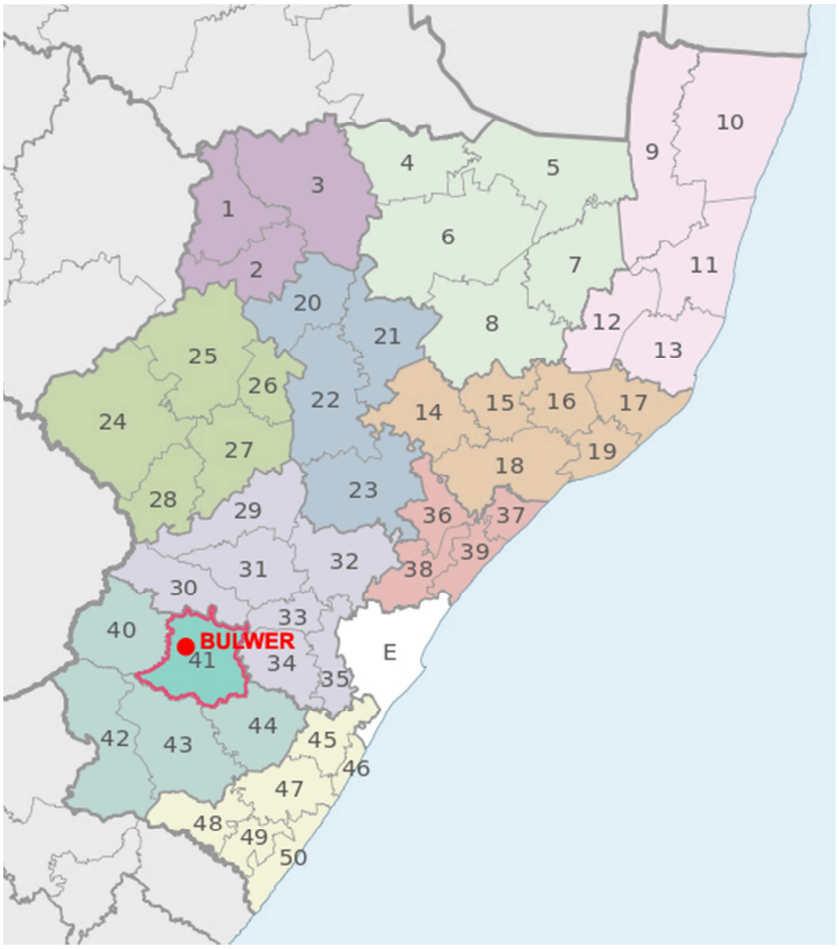


Figure 3-2: Map of the KwaZulu-Natal Province with the district and Local Municipalities, marking the Ingwe Local Municipality boundary and the location of Bulwer.

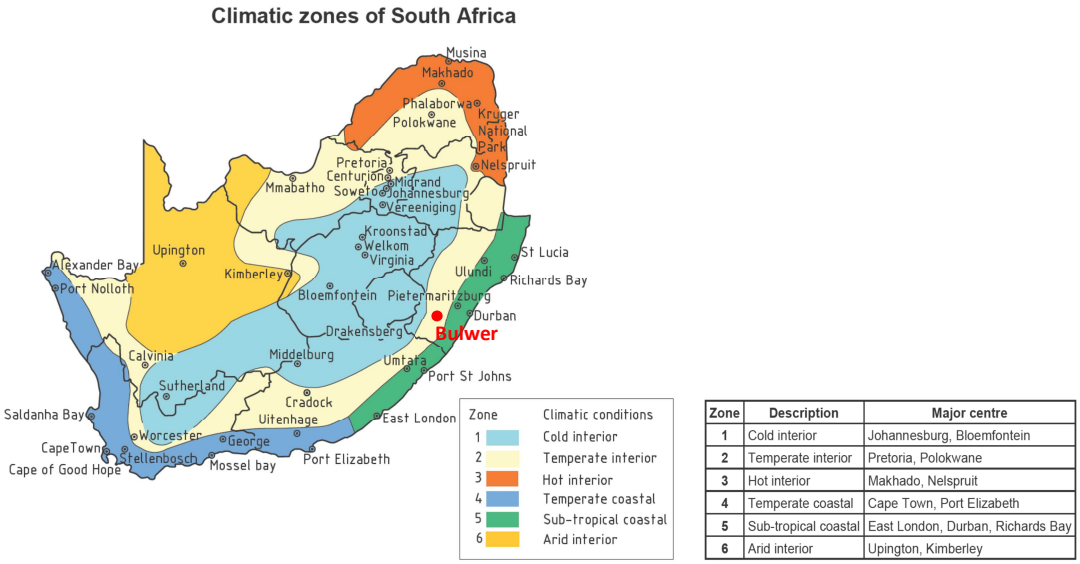
The R617 is the only internal access that connects the three tows of Bulwer, Boston, and Donnybrook and it was identify as a primary corridor with greatest potential in terms of tourism and service growth, being a route with areas of scenic beauty and landscape (Ingwe Local Municipality, 2007).

Bulwer has an organic settlement pattern with linier development occurring mainly along the R617 provincial road. It has contextual growth along the hill that restricts growth to a certain extend with difficult development opportunities. There is however potential development opportunities on the eastern side of the R617 (Figure 3-3).

Figure 3-3: Contextual Settings. (Source: Bulwer Urban Regeneration Plan)

3.3. Climate

The climate is classified as “temperate interior” according to SANS 204, being Bulwer in the zone 2 of the Climatic Zone map of South Africa (SABS Standards Division, 2011).



Zone	Description	Major centre
1	Cold interior	Johannesburg, Bloemfontein
2	Temperate interior	Pretoria, Polokwane
3	Hot interior	Makhado, Nelspruit
4	Temperate coastal	Cape Town, Port Elizabeth
5	Sub-tropical coastal	East London, Durban, Richards Bay
6	Arid interior	Upington, Kimberley

Figure 3-4: Climatic zone map of South Africa (SABS Standards Division, 2011)

Nevertheless, the winter is quite hard, due to the proximity of the Drakensberg Mountains, with night temperature that frequently drops below 0°C during the coldest months. The graph of Figure 3-5 shows the monthly temperature in Bulwer in 2012, recorded by the weather station of the South African Weather Service. The graph demonstrates that for the context of Bulwer green design strategies, especially in terms of passive building design, have to deal with challenging climatic conditions and to mitigate the risk of very cold indoor temperature in winter and overheating in summer.

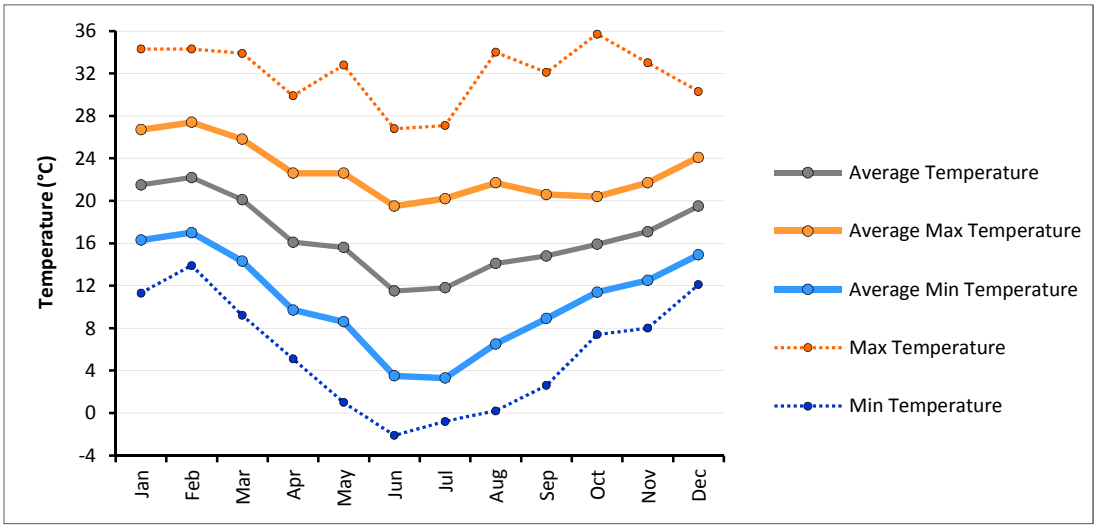


Figure 3-5: Monthly maximum, minimum, average, average maximum and average minimum air temperature in Bulwer in 2012 (analysis of data obtained from the South African Weather Service)

At the time of the investigation, the weather stations around Bulwer and surrounding areas could not provide comprehensive hourly weather data to run effectively dynamic building energetic analysis, due to the unavailability of certain sets of data (i.e. global and diffuse horizontal solar radiation, direct normal radiation). Therefore, the official hourly weather data delivered for the climatic zone 1 of SANS 204 (related to Johannesburg) was used as a valuable reference for the energetic prediction, being closer to the climatic conditions of Bulwer than the milder hourly weather data of the zone 2.

3.4. The built environment

In Bulwer the built the environment could be classified in three components:

- ✓ Residential component: it is situated on the eastern boundary of Bulwer. There are further residential activities at a much lower density along side streets just of the R617, which separates the low cost units from the government units. There are no informal dwelling units within the Bulwer Study Area. The quality of the houses in the town is various, related in particular to the period of construction.

Figure 3-6: Examples of residential building in Bulwer. (Source Googlearth)

- ✓ Commercial component: the quality of the commercial buildings within Bulwer varies in condition, with the newer stores in obvious better state. The qualities of the buildings are generally in good condition.

Figure 3-7: Examples of the commercial component of the built environment in Bulwer. (Source Googlearth)

- ✓ Public Open Space: in Bulwer consists largely of passive opens spaces with one sports field utilised by the community and the school. Passive open spaces are unkempt. Other Open Spaces consist of sidewalks where pedestrians, traders and vehicles interact. There are no well-developed open spaces for pedestrian movement and outdoor activities.

Figure 3-8: Governmentalal office building in Bulwer. (Source Googlearth)

3.4.1. Housing and the RDP settlement

The Ingwe Municipality has developed a Housing Plan in 2007 and over the past decade a number of formal housing projects, drawing on subsidies from the Department of Human Settlements, have been initiated. By far the greatest need for housing services upgrade is in the tribal areas where the majority of the rural

population are located. The land is mostly owned by the Ingonyama Trust and administered by the Tribal structures.

Indicated in the Ingwe LM IDP Review2012/2013, there are currently three approved housing projects located in Creighton, Bulwer and Donnybrook. The Creighton project has been completed. The Donnybrook project is on hold pending the approval for the construction of a reticulated water supply to cater for the increased demand arising from the housing development.

The Bulwer project has started and is in the process of implementation. Between 2008 and 2011, an RDP settlement of 313 units was built in the southern part of the town, allocating about 1500 people working in the surrounding area especially in farming, dairying and forestry sector.

Figure 3-9: Othophoto and aerial view of the RDP settlement in Bulwer

The typology is the traditional RDP one-storey detached house replicated without any consideration of green criteria, social interaction and facilities for inhabitants. At the time of the investigation, some municipal basic engineering services were still absent (i.e. water reticulation).

Figure 3-10: Panoramic view of the RDP settlement in Bulwer

Figure 3-11: View of the RDP settlement

Figure 3-12: View from the site visit at the RDP settlement

Figure 3-13: View from the site visit: an RDP unit based on the detached single storey housing typology

3.4.2. The Urban Regeneration Plan

In 2013 the Municipality commissioned a Urban Regeneration Plan to provide guidance towards the further development of land, including the prevision for a residential development close to the RDP settlement.

The redevelopment of Bulwer town has been identified as a catalyst project by the Ingwe Local Municipality and the Sisonke District Municipality not only to stimulate the local economy within the town, but also to guide possible further functions of the town as a potential administrative centre to the municipality. It is anticipated that the Bulwer town and its CBD is changing and needs to be restructured to accommodate growth and ensure integration of existing and potential future land uses.

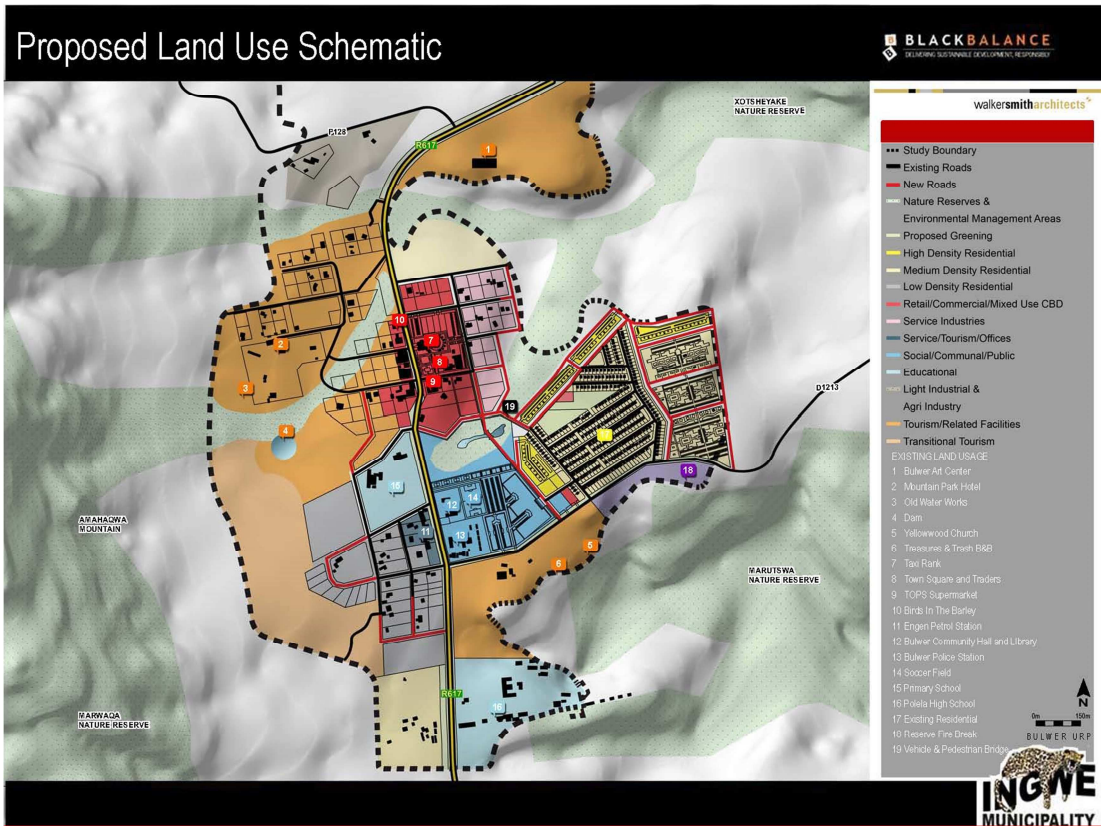


Figure 3-14: Land Use schematic. (Source: Black Balance & Walker Smith Architects Bulwer Regeneration Plan, 2013)

This research started from the analysis of the existing RDP settlement and investigated a potential green development scenario for the new residential area. The following chapter describes in detail the methodology adopted by the research.

CHAPTER 4: METHODOLOGY

4.1. Introduction

The challenge of a sustainable development of low-income housing in South Africa needs to be addressed through an integrated and holistic approach. The sustainability, in fact, must be assessed by multiple perspectives, including various and conflicting viewpoints (Espinosa *et al.*, 2008).

Various research investigated alternative planning and design strategies to provide higher quality of housing to low income communities. They focused on various aspects of housing design and urban development. The eThekwini Municipality, for example, concentrated on the study of different housing typologies for low-income households in relation to the local context (eThekwini Municipality, 2010). Other research studied the implications of urban densification strategies for the poorest households (Zhu, 2012) and compare different densification layouts to evaluate the potential benefits for the communities **(**Metroplan, 2012).

Nevertheless, very few research investigated the potential implications in terms of indoor comfort and energy saving for the settlements and housing units due to the implementation of alternative design solutions and building typologies. The study conducted by WSP (2010) appreciated the benefits of different wall technologies, but only applied to the traditional detached RDP house.

Furthermore, the alternative design criteria should be linked to a bottom-up approach investigating firstly the needs of local households and communities. Several studies and projects demonstrated the importance of the participation of the communities from the early stages of the decision making process, in order to define appropriate solutions responding to their actual needs and requirements. For example, in the Cato Manor Green Street Retrofit Project in Durban a pre-retrofit field audit was undertaken to better understand the main critical issues experimented by households in terms of sustainability aspects (GBC SA, 2012).

In order to address effectively the potential of green design strategies on low-income housing development, the methodological framework of this research was hence based on the synergistic interaction between the different research methods mentioned above. Theoretical methods based on a critical literature review were in fact combined with the results of a participatory approach to define the strategic

guidelines for the following scenario analysis (connecting a housing typologies study with the assessment of densification criteria and a dynamic building energy and comfort performance analysis) applied to the case study of the RDP settlement in the town of Bulwer.

The case study approach was used being appropriate to investigate and apply the proposed methodology and design strategies to an actual example of low-income housing development. This narrow approach was firstly adopted through participatory methods, via a survey, interviews and a field audit conducted to the local low-income community, then through a scenario analysis based on the investigation of multi-scale strategies and design alternatives, comprising experimental assessments of energy and indoor comfort parameters. The study hence combines qualitative and quantitative approaches depending on the target and the aim of each research step, that however were strictly interdependent.

The research approach and methods were oriented to investigate and define sustainable design criteria for new low-cost settlement in the South African context. Although some design strategies were specifically defined as suitable for the local context of the case study (i.e. according to the local climate), the proposed holistic and integrated design approach can be generalised also to different contexts and intended as a critical framework and guideline for the design process to reach sustainability targets. Greening the low-cost settlements should be oriented not only to reduce environmental impact and energy consumption, but primarily intended as an opportunity to improve indoor environmental quality of houses and health, strive social inequity, promote social interaction, create job opportunities, and finally improve the quality of life of households and community (Fig. 4-1).

The foundation of this holistic approach is that only the systematic and simultaneous control the three key components environmental, social and economic, driven by green design principles and community engagement, can effectively activate the sustainable development of the built environment (Fig. 4-2).

The synergy between the different research methods (theoretical, participatory, narrow approach with scenario analysis based on design alternatives and experimental assessments) is oriented to an optimisation process of the design choices to meet sustainability targets with affordable and effective solutions.

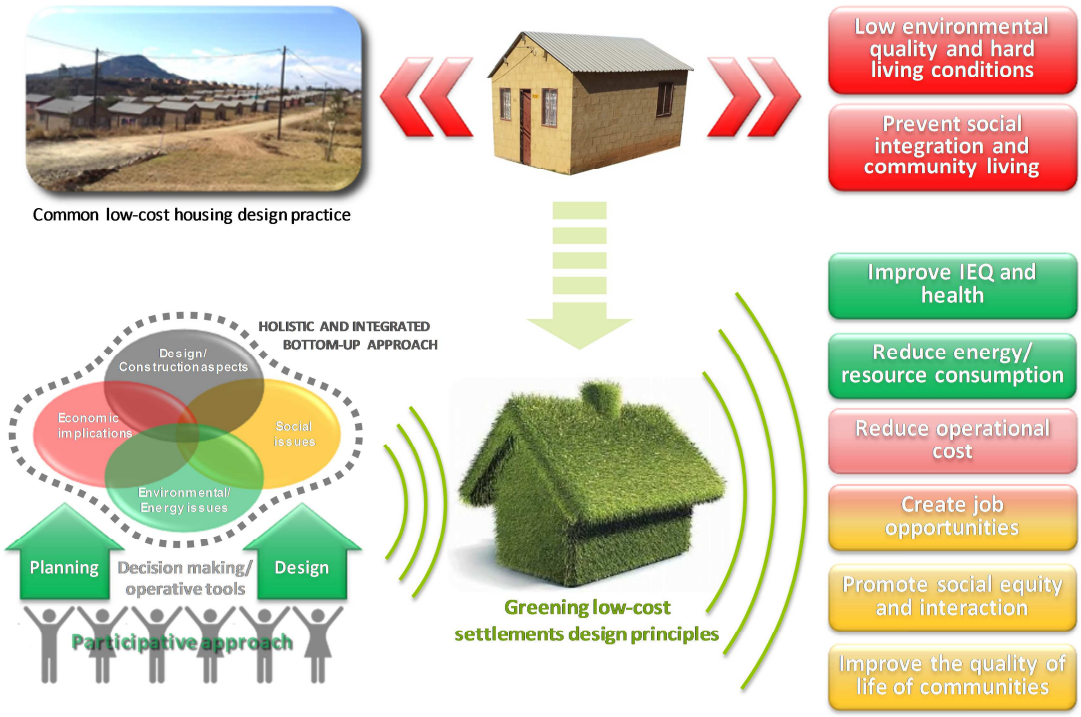


Figure 4-1: Research approach and aims

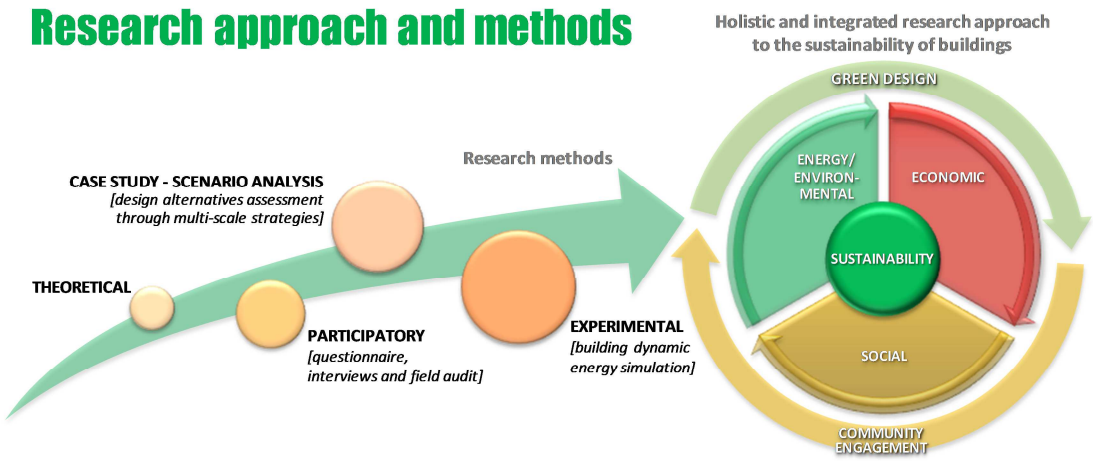


Figure 4-2: Research approach and methods

The following paragraphs describe the various research methods adopted in the study.

4.2. Theoretical approach

A theoretical method focused on the available literature was used to define background information about the critical aspects related to the sustainable development of low-income housing in South Africa.

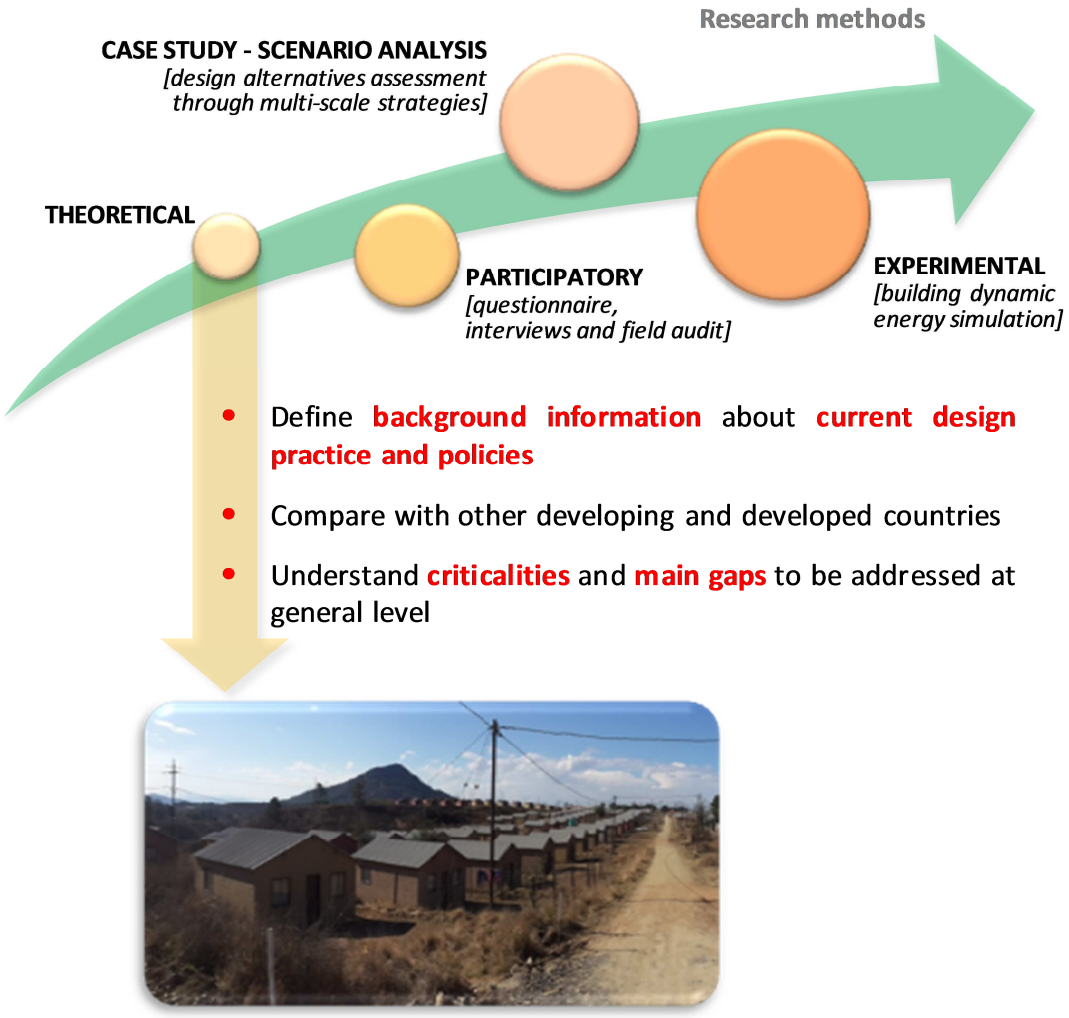


Figure 4-3: Aims and objectives of the theoretical method

A critical literature review was conducted on South African low-income housing sector, its current design practice and related policies, with regard to the new regulation about sustainability and energy requirements.

The comparison of recent projects in South Africa and other developing countries contributed to understand best practices and innovative green solutions adopted in different low-income housing initiatives, and to identify the criticalities and the main gaps to be addressed in the South African context.

Other references from developed world were considered to compare the approach to low-income housing design with different perspectives than developing countries.

The main findings from the literature review were summarised in the form of cross comparative tables regarding policies and approaches to the topic from different perspectives and contexts.

4.3. The participatory method: the survey, the field audit and the interviews in the existing RDP settlement in Bulwer

The second research method refers to a bottom-up approach based on a participative process that comprised the engagement of the local community. A post-occupancy questionnaire was created, organised with questions with multi-choice answers regarding environmental, social and economic impact categories (energy, water, comfort, employment, transport, health, social aspects).

Using the questionnaire, a survey, a field audit and interviews were personally conducted on a sample of thirty households in the existing RDP settlement in Bulwer. The assumptions and limitations related to the selection of the sample are discussed in the sub-chapter 4.5. The aim was to gain feedback from the inhabitants and to stimulate the participation of the community in the decisional phase and in the definition of design strategies for future green low-cost housing development derived from their needs and actual opinion on the current living conditions. The survey was also oriented to understand the availability of inhabitants to the potential implementation of green measures, at building and community level, which often imply social and behavioural adjustments.

The participative process is integral part of the methodology as well as foundation of the following research steps regarding the assessment of design alternatives.

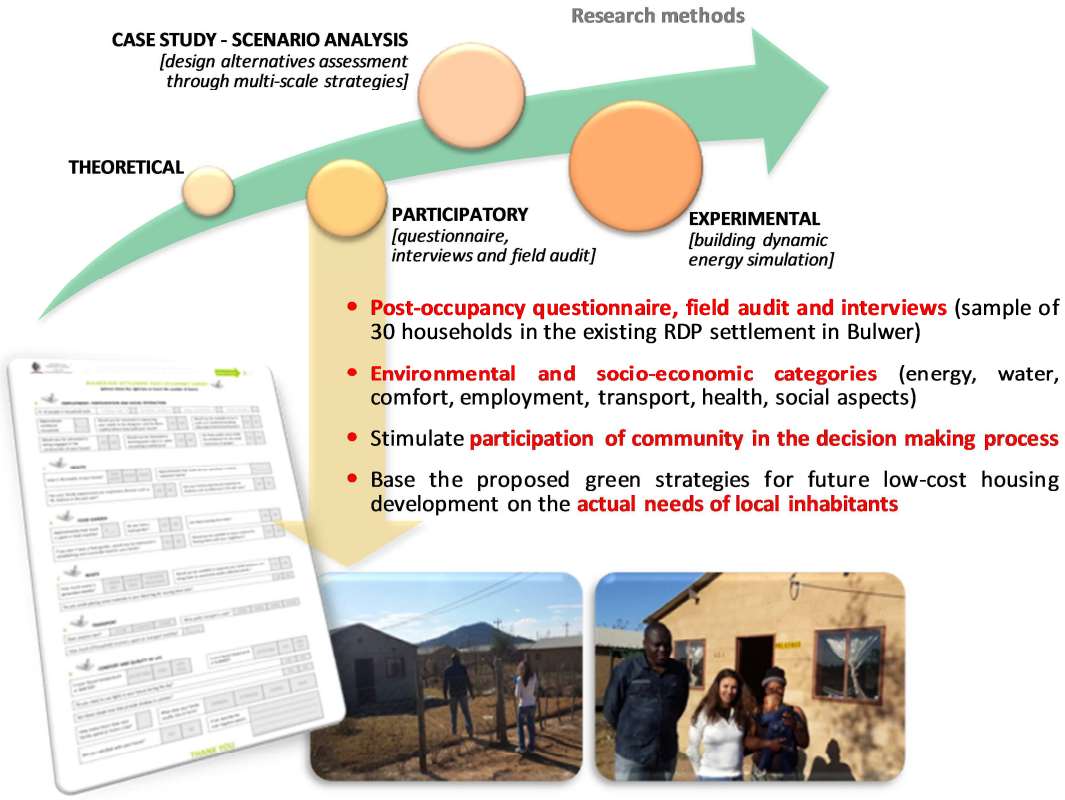


Figure 4-4: Contents, aims and objectives of the survey (participatory method)

4.3.1. Structure and contents of the questionnaire

The questionnaire was structured considering valuable references and literature about the investigation of sustainable living conditions in low-income communities and related occupants' perception.

Particularly, research projects in the South African context were analysed, for example the Cato Manor Green Street Retrofit Project in Durban (GBC SA, 2012). These projects and other international studies, aimed to the post-occupancy evaluation for the same target group, were used to support the definition of the sustainability indicators, impact categories and questions to be submitted to the inhabitants. Wells and Harris (2007) for instance studied the effects of housing on mental health through a survey regarding the quality of life, submitted to the women living in low-income settlements in USA. The study demonstrated the benefits of the participatory process in terms of community involvements and satisfaction.

Then, the questionnaire was customised to the specificity of the local context and the aims of the study. It was submitted to the residents of the RDP settlement in Bulwer through a field audit and interviews that I personally conducted with the assistance of officers from the local Municipality, particularly Mr Szuluthe Dlamini and Mr Zibokwakhe Mncwabe. The survey and the field audit were conducted with the permission of the residents, translating all the questions to Zulu language.

Each household participant to the questionnaire was engaged for about 30 minutes, in which firstly background information, as the research topic, the purpose and the structure of the questionnaire were explained, then the questionnaire was submitted and the field audit was conducted to achieve all the necessary information about the settlement.

Figure 4-5: Pictures from the field audit and interviews

The questionnaire was structured in the form of simple questions with multi-choice answer to make it easy to understand and immediate to complete as much as possible. The questions were organised in sustainability impact categories that focused on the following topics:

- *Household demographic data and housing type:* the first category concerned the demographic data of the household and the information about the unit in terms of rooms layout and subsequent living conditions. Particularly, the questions aimed firstly to evaluate the number of people living in the unit, how many adults and children, if they are a renter or owner; secondly to explore the spatial development of the units, in terms of number of rooms available, presence of separated sleeping space, presence of any extension already made or intention

to extend the unit. The last question concerned previous residence before moving to the RDP settlement.

- *Energy (heating, cooling, cooking, water heating, lighting):* this category included questions regarding the equipment and methods used for space heating, cooling, preparing meal, lighting and water heating, related energy sources and operational cost. Also, some questions investigated the presence of passive systems to mitigate the climate conditions (i.e. presence of ceiling) or reduce energy consumption (i.e. use of wonderbag to heat meal). Indeed, this serie of questions was very important to understand the quality of life of households living in the settlement, linking the response both to the low available resources and the poor quality of facilities and infrastructure. The last question inquired into the interest of households in a green living manual that helps them to reduce energy consumption and implement effective energy and resource saving measures.

- *Water, plumbing facilities and rainwater:* Water is another basic service often not guaranteed from Municipalities in South African RDP settlement. This category focused on water source, bathroom facilities, and possible water leaks. Questions regarding the potential reuse of grey water, as well as the interest in rainwater tank for backup water supply and food gardens, were also included in order to integrate the community feedback in the definition of the green strategies considered for the scenario analysis.

- *Employment,* participation and social interaction: Social interaction and participatory processes based on a bottom-up approach in the decision making and design phase represent a crucial turning point to achieve sustainability targets and positive outcomes for the development of a low-income settlement. The aim is that the community works together to express its specific need and actively participate to the decision making and design choices. Social interaction and facilities can also foster the creation of a sense of community and improve the community living within the settlement. Questions regarding the potential interest in expressing final users' needs to the designers and Municipalities as well as in being involved in the construction phase (and also in learinng green jobs), may emphasise the importance to engage the community from the predevelopment phase of the settlement. Other questions, concerning the opinion on different housing typologies and related social implications (i.e. multi-unit residential building), and the interest in learning green jobs or being involved

in community work, had been meditated to improve the community understanding of the potential role of green implementations.

- *Health:* there is a strong correlation between poor quality of life and diseases, supported by several research (Lowa *et al.*, 2013). Housing quality plays a fundamental role to achieve better living conditions in terms of health. The questions in this category of the survey focused on the health condition of the inhabitants and the approximate bill in medical treatment.
- *Food garden:* South African RDP settlements are almost unproductive in term of landscape and green features, as for example threes. Rethinking the opportunity to spread green facilities, as well as food gardens or fruit threes, may be a great chance to produce good food, to create a sense of community, to assure job opportunity, to help families' income. For all these reason, this category explored the interest of the RDP community in green initiatives like private and community vegetable gardens
- *Waste:* Waste collection, treatment, disposal and recycle are an urgent issue for South African low-income communities, for which correct waste management strategies need to be implemented. This category hence investigated the amount of waste produced by households, possible measures adopted to reuse waste products and availability to undertake a separate waste collection.

Figure 4-6: Dispersion of waste within the settlement

- *Transport:* the lack of efficient and cheap public transport facilities in South Africa is maybe one of the main issues for low-income communities that cannot effort an own car. This category was aimed at understanding what kind of public transport the inhabitants used and how much of their income was spent for transportation.

- *Comfort and quality of life:* the last section of the questionnaire focused on the indoor comfort perception of residents, in terms of summer, winter thermal comfort and day lighting. Comfort requirements were related to the occupancy period during the day depending on the habits of households. The last question inquired into the overall house satisfaction, giving occupants the opportunity to describe other negative aspects of the house.

The following pages show the questionnaire submitted to the households. The outcomes of the survey are discussed in the following chapter “Results and discussions”.

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The outputs of the survey will be used only for research purpose
[UKZN | School of Engineering | Discipline Civil Engineering | MSc Eng Student: Barbara Murru]

Bulwer survey 1/2

BULWER RDP SETTLEMENT POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

1. HOUSEHOLD DEMOGRAPHIC DATA AND HOUSING TYPE

House N°:		N° of adults:		N° of children :	
Number of years lived here:		Are you the owner or a renter?		OWNER	RENTER
How many rooms do you have?		Do you have dedicated sleeping space?		YES	NO
Are there existing formal extensions?	YES	NO	Are there existing informal extensions/outhouses?	YES	NO
			Are you planning to extend your house?	YES	NO

What did you live in before moving here?	ROOM	BRICK HOUSE	BACKYARD	INFORMAL SETTLEMENT	CAR	CARAVAN	TENT

Why did you decide to live here?	WANTED A PLACE OF MY OWN	NEEDED MORE SPACE	EXPERIENCED CONFLICT WITH PEOPLE LIVING WITH ME	COULD NOT AFFORD RENT	EVICTED BY LANDLORD	WANTED TO BE CLOSER TO WORK

2. ENERGY (HEATING, COOLING, COOKING, WATER HEATING, LIGHTING)

Approximately how much do you pay for electricity monthly?	R_____	What kind of electricity meter do you have?	PREPAID	ACCOUNT

Where do you get electricity from?	OWN ELECTRICITY BOX	ELECTRICITY POLES	NEIGHBOURS

What energy sources do you use for heating?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY
What energy sources do you use for preparing meals?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY

What cooking, heating and cooling appliances are being used in the house?	2 PLATE STOVE	MICROWAVE	HEATER	KETTLE	FAN	FRIDGE	OVEN

Do you use a wonderbag for preparing meals?	YES	NO			
Do you use a heater to keep warm in winter?	YES	NO	Is there a ceiling?	YES	NO
Do you use a fan to cool your house in summer?	YES	NO			

How do you heat up water for washing (personal, laundry, dishes)?	GEYSER	KETTLE	PLOT ON STOVE	OTHER

How many times a day do you heat up water with a kettle/on stove?		How many litres do you heat up each time?	

How many light fittings are being used in main house?	N° OF STANDARD INCANDESCENT:		N° OF COMPACT FLUORESCENT:

Would the owner /resident be interested in a building user's guide that teaches how to save energy in your house?	YES	NO

3. WATER, PLUMBING FACILITIES AND RAINWATER

Approximately how much do you pay for water monthly?	R_____	Is there a water meter?	YES	NO

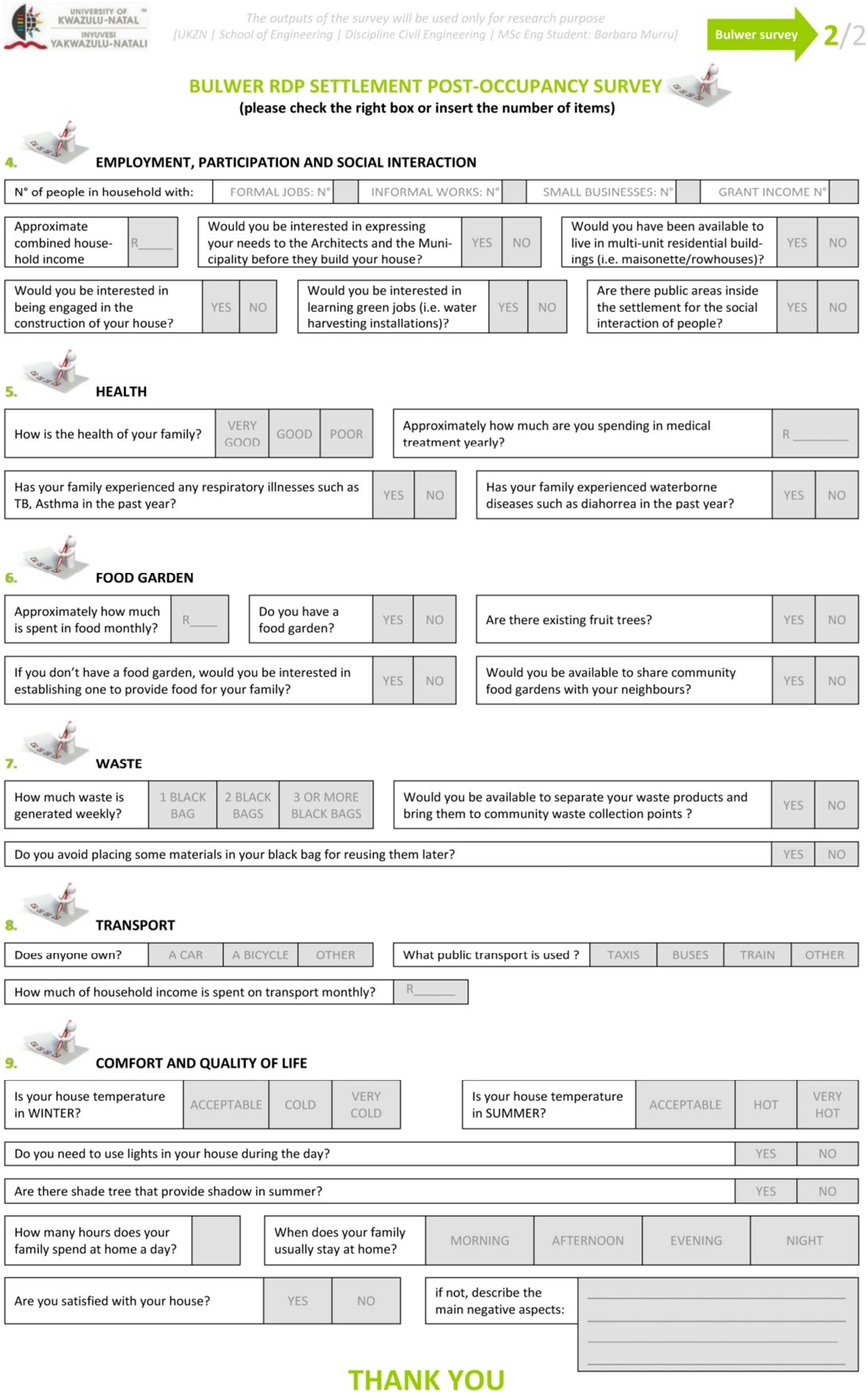
Do you use the communal standpipe for any of your water needs?	YES	NO	How do you get water?	INDOOR TAP	OUTDOOR TAP	COMMUNAL TAP	NEIGHBOUR
---	---	---	---	---	---	---	---

Is there any property leaks?	YES	NO

What bathroom facilities are there in your house?	TOILET	SHOWER	BATH	BASIN

What is happening to greywater after washing dishes or clothes??	HAVE A SINK CONNECTED TO THE SEWER	THROW IN ROAD, YARD OR NEARBY	POURED DOWN DRAIN IN SHOWER	USED IN FOOD GARDEN

Would the owner / resident be interested in a rainwater tank for backup water supply and for a food garden?	YES	NO



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The outputs of the survey will be used only for research purpose
[UKZN | School of Engineering | Discipline Civil Engineering | MSc Eng Student: Barbara Murru]

Bulwer survey 2/2

BULWER RDP SETTLEMENT POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

4. EMPLOYMENT, PARTICIPATION AND SOCIAL INTERACTION

N° of people in household with:	FORMAL JOBS: N°		INFORMAL WORKS: N°		SMALL BUSINESSES: N°		GRANT INCOME N°	

Approximate combined household income	R_____	Would you be interested in expressing your needs to the Architects and the Municipality before they build your house?	YES	NO	Would you have been available to live in multi-unit residential buildings (i.e. maisonette/rowhouses)?	YES	NO

Would you be interested in being engaged in the construction of your house?	YES	NO	Would you be interested in learning green jobs (i.e. water harvesting installations)?	YES	NO	Are there public areas inside the settlement for the social interaction of people?	YES	NO

5. HEALTH

How is the health of your family?	VERY GOOD	GOOD	POOR	Approximately how much are you spending in medical treatment yearly?	R _____

Has your family experienced any respiratory illnesses such as TB, Asthma in the past year?	YES	NO	Has your family experienced waterborne diseases such as diahorrea in the past year?	YES	NO

6. FOOD GARDEN

Approximately how much is spent in food monthly?	R_____	Do you have a food garden?	YES	NO	Are there existing fruit trees?	YES	NO

If you don't have a food garden, would you be interested in establishing one to provide food for your family?	YES	NO	Would you be available to share community food gardens with your neighbours?	YES	NO

7. WASTE

How much waste is generated weekly?	1 BLACK BAG	2 BLACK BAGS	3 OR MORE BLACK BAGS	Would you be available to separate your waste products and bring them to community waste collection points ?	YES	NO

Do you avoid placing some materials in your black bag for reusing them later?	YES	NO

8. TRANSPORT

Does anyone own?	A CAR	A BICYCLE	OTHER	What public transport is used ?	TAXIS	BUSES	TRAIN	OTHER

How much of household income is spent on transport monthly?	R_____

9. COMFORT AND QUALITY OF LIFE

Is your house temperature in WINTER?	ACCEPTABLE	COLD	VERY COLD	Is your house temperature in SUMMER?	ACCEPTABLE	HOT	VERY HOT

Do you need to use lights in your house during the day?	YES	NO

Are there shade tree that provide shadow in summer?	YES	NO

How many hours does your family spend at home a day?		When does your family usually stay at home?	MORNING	AFTERNOON	EVENING	NIGHT

Are you satisfied with your house?	YES	NO	if not, describe the main negative aspects:	_____ _____ _____ _____

THANK YOU

Figure 4-7: Questionnaire form

4.4. The scenario analysis: investigation of multi-scale green design strategies for a potential low-cost housing development in Bulwer

The subsequent phase was a scenario analysis of the local case study, considering a potential low-cost housing development in the town of Bulwer. The scenarios investigated design alternatives through multitask assessments, based on sustainability indicators, assessing multi-scale green strategies that related the scale of the settlement to the scale of the building, single unit, building components and materials.

The adopted green design strategies focused primarily on densification criteria, building typology study, passive design principles, and low cost green implementations. The sustainability indicators used for the assessment were land use, people allocated, environmental and energy impacts, indoor comfort, social implications, safety and cost effectiveness.

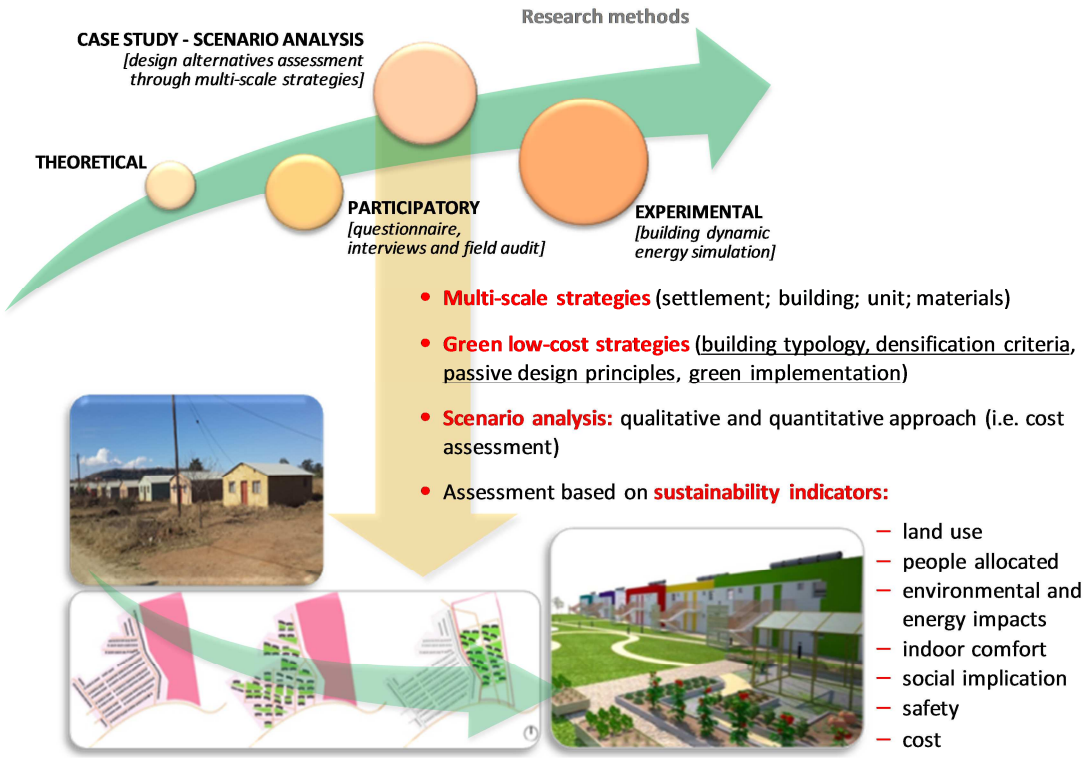


Figure 4-8: Criteria and contents of the scenario analysis

The core concept leading the investigation is that in low-income housing design, due to the cost constrain and affordability criteria, the focus should be

switched from the environmental and economic assessment of the single house, traditionally identified with the detached house, to a broader analysis of the settlement. This should include different building typologies and schemes of use of land, more compacted layout with community shared services and reduced cost for municipal engineering services. This approach could realise global economic savings that can be invested in a better housing quality and achieve environmental and social benefits both for households and the whole community.

The proposed scenario can be intended as a potential low-cost housing development option that could be undertaken based on future needs of the local and district municipality. However, rather than a specific planning and design project output, the main aim of the study is to demonstrate how a green integrated approach to the design of low-cost settlements could potentially improve the quality of life of the community and reach environmental, social benefits and economic sustainability. Furthermore, some proposed green measures (i.e. building typology strategies, planning and layout strategies, densification criteria, etc.) could benefit also other target group of households and are hence suitable to be extended to other housing sectors (i.e. affordable housing).

Firstly, a study on the layout of the settlement was conducted to investigate the potential benefits of alternative building typologies and densification criteria compared to the common practice. This study comprised two steps: firstly a building typology assessment, whose results were summarised in a matrix that compared through four grades of evaluation the traditional housing design practice of the existing RDP settlement with two suitable variations for the new residential development. The evaluation in mainly qualitative, considering for each alternative positive and negative impacts in terms of environmental, social, safety and economic implications. Secondly, a strategy of densification was applied and assessed to understand and quantify the potential outcomes in terms of people allocated, reduced land use, compacting the layout of the settlement and consequently reducing the extent of municipal engineering services.

From the results, a scenario of the most suitable option was developed and assessed to quantify the potential benefits, especially in terms of energy and environmental impacts. This quantitative investigation was conducted on a layout derived from a preliminary qualitative energetic analysis of the settlement, aimed to achieve environmental and energy efficient solutions for the community and the

single building units from the early design stages. The detailed energetic analysis was an experimental investigation that adopted thermal modelling of the selected design alternatives to predict the energetic behaviour of the houses and subsequent comfort indoor conditions. Finally, a preliminary cost assessment compared the proposed green design approach and implemented strategies with the common prctice.

The following paragraphs describe in detail each step of the scenario assessment.

4.4.1. Housing typologies study

The housing typologies study evaluated the potential effects related to the transition from the common practice to alternative housing typologies.

The study was developed considering best practices and available literature, identifying suitable variations that could improve the quality and sustainability of resultant living environment. Some Municipalities adopted this method to define future guidelines for housing development plans. For example, the Architecture Department of the eThekwini Municipality developed a housing typologies study to investigate housing typologies for the delivery of new housing projects in the local context, integrating town planning, urban design and architecture components (eThekwini Municipality, 2010).

Although the South African government from 1994 has delivered over three million houses to low-income households, it is well recognised, as motivated in the literature review, the lack in terms of social, urban and environmental sustainability that the usual detached typology based settlements have produced. Housing in fact should not be intended only as physical structures but as one of the main contributions to create the sense of place (Teo & Huang, 1996).

The aim of the housing typologies study was to explore the potential improvement in terms of housing quality, functional aspects, environmental and energy impacts, socio-economic implications, through the comparison of different building typologies, and related unit types and site layout generated. The cross-comparison of different hypothetical typologies showed positive and negative aspects of each option with regard to selected sustainability indicators, electing the most suitable typology for the context of the case study.

In this research, the housing typologies study was hence a critical part of the scenario analysis aimed to define effective green strategies for a potential sustainable housing development in Bulwer.

The investigation referred primarily to the following criteria:

- **house quality**, achieved through the interaction between the natural site (vegetation, physical characteristic of the site, etc.), the layout of the settlement and buildings, the artificial factors (services, transportations, etc.) and the dwelling layout;
- **households' background**, recognising the households' needs and frustrations, habits, as well as the socio-cultural factors and ambitions;
- **housing typology**, selected according to the actual requirements in order to keep out undesidered scenarios;
- **correlation between households and housing typology**: the correlation between households needs and housing type generate a matrix of possible scenarios where the households profile is linked to the housing type that better satisfies the expressed needs and requests.

Based on the background of this research, the information gathered from the literature, the South African socio-economic conditions and the context of the case study, the research promoted two possible alternative housing typologies, analysed in order to evaluate advantages and disadvantages.

The housing typology study was structured in six phases:

- *Identification of common practice:* firstly, the South African common practice, in terms of low-income state subsided unit, was identified. It was represented by the single detached unit already described in the literature review.
- *Investigation of alternative housing typologies:* Then, considering the aims and objectives of the research, the main findings from the literature review, the local context the results of the survey, three suitable alternative housing typologies were proposed. These typologies promoted a medium or medium-high density development scenario.

- *Concept green design of the alternative typologies and related units:* for each housing typology, a concept design of the building and units was developed considering basic green building design principles as orientation, layout plan, window to wall ratio, passive heating and overshadowing criteria. Therefore, plan and elevation drawings and rendering of the proposed typology were produced (included in the chapter results and discussion).
- *Identification of sustainability indicators:* in order to evaluate the advantages and disadvantages of each typology, four sustainability indicators were defined. Each indicator aimed to identify strengths and weaknesses of each typology of the potential issues or benefits produced with regard to the respective field of interest. The indicators were the following:
    - Economy: it assessed primarily construction, management and operational cost.
    - Social implications: this indicator evaluated the features related to the social environment as privacy, sense of space, community areas, social interaction, job creation.
    - Energy and Environment: it analysed the potential energetic and environmental impacts of each typology, considering also the suitability for passive design strategies implementation.
    - Safety: it referred to safety level in terms of surveillance and visibility related to the different housing schemes, considering also consequent relation with neighbours that the typology would establish.
- *Matrix of housing typologies:* a matrix of typologies analysed and cross compared positive and negative aspects of each typology, with regard to the common practice, using the selected sustainability indicators. The assessment followed a mainly qualitative approach that critically analysed the potential implications related to housing quality and living conditions. The aim was to define a cross comparison between the existing layout and the different schemes suitable for the local context. The comparison was assessed by four grade of evaluation: highly negative, negative, positive and highly positive with regard to the impact on the indicator's field.

- *Election of the most suitable housing typology:* the outcomes of the cross comparison elected the most suitable housing typology that could reach the highest benefits for the aim of the study.

The outcomes of the housing typologies study are discussed in the following chapter.

4.4.2. Densification strategy

Traditional RDP settlements are usually generated by the repetition of units within the site, creating a monotonous and static environment. The common practice produced low-density developments, characterised by an unsustainable indiscriminate use of land and large extent of engineering services.

Through the promotion of medium and medium-high density housing typologies, a densification strategy was hence applied within the scenario analysis. The strategy assessed the potential impact in terms of units and people allocated, reduced land use, reduction of engineering services due to the more aggregate layout of the settlement.

Previous projects, in which a densification strategy was applied, were considered to support the adopted research method. For example, Metroplan Town and Regional Planners, which designed and managed the Sakhasonke Village project in South Africa, firstly developed a comparative analysis between low-density and medium-density scenarios within the layout of the Sakhasonke settlement **(**Metroplan, 2012).

The investigation on the densification strategy was organised in three stages. In the first stage, the existing low-density development characterizing the RDP settlement in Bulwer was analysed, in order to evaluate issues related to the settlement and challenges for a hypothetical higher density development. The available information and maps from the Urban Regeneration Plan of Bulwer, orthophotos and cad drawings were considered to better contextualise the study. These references were integrated through a site visit, aimed to produce a photographic portfolio of the built environment and observe the effect of the low-density development on the community's perception, investigated also through the survey.

The benefits achievable through a densification strategy referred to the following aspects:

- *Limited use of land*: this considered the impacts of housing development on the surrounding environment, in terms of extent of land use.
- *Travel distance and transportation*: this aspect evaluated the distance between the settlement and the main services offered from the town, and consequent environmental pollution of transportation, and the internal distance within the settlement.
- *Cost of infrastructure:* medium and high-density scenarios limit the extent and cost of municipal engineering services.
- *Socio-economic implication*: the compactness of medium and high-density developments, opposed to the fragmentation low-density layouts, can generate positive socio-economic impacts due to the aggregate model.

According to these considerations, the research promoted a densification strategy as a crucial step to guarantee natural and urban sustainability in a potential housing development scenario of Bulwer and benefits for the community.

In the second stage, the densification strategy was therefore applied to a hypothetical scenario based on the same boundaries of the exiting settlement. The alternative housing typologies, previously designed, substituted the RDP units, allocating within the same boundaries a higher number of units and households.

The last stage concerned the application of the densification strategy to the new residential development area (development scenario), defined by the Bulwer Regeneration Plan.

In order to appreciate the benefits related to the densification strategy and compare the different scenarios (existing, hypothetical and development scenarios), the following indicators were used:

Table 4-1: Indicators of densification

INDICATOR	UNIT	DEFINITION
Land area occupied	ha	Indicate the size of the settlement. Measurements of area are given in hectares (1,000 m X 1,000 m or 10,000 square meters)
Number of units	-	Indicate the actual number of unit within the settlement
Unit gross floor area	m^2	Indicate the total area of the covered floor space Measurements of area are given in square meters (1 m X 1 m or 1 square meters)
Gross density	1/ha	Indicate the rapport between number of units and the land occupied
Roads area	ha	Indicate the total area of the roads within the settlement. Measurements are given in hectares.
Population allocated	-	Indicate the number of people living in each unit, assumed at five.
Population density	1/ha	Indicate the rapport between the total number of people and the land area occupied

Based on these indicators, the results were discussed and commented on chapter 5.

4.4.3. Experimental methods: dynamic building energy and comfort performance analysis

After assessing alternative building typologies potentially beneficial for the aim of the study, a detailed quantitative energetic and comfort analysis was conducted on the proposed housing development scenario.

The construction and laboratory experiments on energetic behaviour of buildings are a costly method to explore potential variations in building designs. Thermal modelling and computer simulations of building energetic behaviour can provide convenient prediction for housing design and avoid large costs for building construction, testing and monitoring (Wang *et al.*, 2009).

Dynamic energy simulation, based on hourly and sub-hourly variation of climatic, energetic and comfort parameters, is the most accurate method to predict actual energetic behaviour of buildings. This is valid especially for climatic areas characterised by high intensity of solar radiation, diurnal temperature variation and both risks of overheating in summer and overcooling in winter, such as the addressed case study. For this reason, for example, the new Building Energy

regulation of Spain adopted calculation methods based on dynamic hourly simulation (CTE, 2007).

The assessment was done using a dynamic building energy simulation programme, Energy Plus, that was developed and issued by the United States Department of Energy and currently is one of the most advanced and well-recognised energy simulation software all over the world. EnergyPlus is a freeware simulation engine using a code written in Fortran 90, without formal user interface (Crawley *et al*., 2000). For this research being an investigation of building design variations, the graphic user interface provided by the software DesignBuilder was used. DesignBuilder is a state-of-the-art software tool for checking building energy, carbon, lighting and comfort performance and one of the most comprehensive user interface to EnergyPlus dynamic thermal simulation engine. For this reason, it can help architects and engineers to study energetic behaviour of the building, at the same time controlling also its architectural aspect and aesthetic quality. In addition, Agreement South Africa recently certified DesignBuilder for the assessment of the energy requirement of buildings as required in Regulation XA3 of Part XA: Energy usage in buildings of the National Building Regulations.

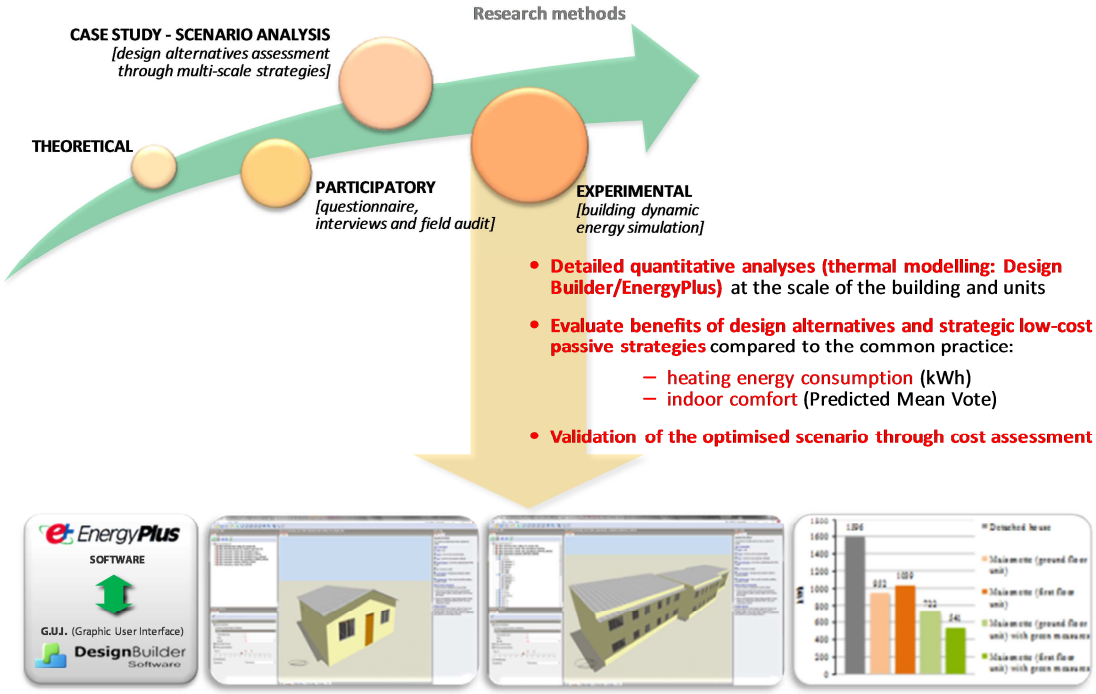


Figure 4-9: contents and aims of the experimental methods using thermal modelling and dynamic building energy simulation software

The dynamic building energy simulations were conducted at the scale of the building and assessed the single units. The layout of the settlement and blocks, as well as the plan of the units, was designed following environmental criteria. Then, the model of the building and the units was built within the software, including all the construction features of each building component, occupancy rates, internal gains and systems based on operational schedules. Finally, the simulations provided a quantitative assessment of the potential benefits of alternative building typologies and low-cost passive strategies compared with the common practice, in terms of heating energy consumption (kWh) and indoor comfort (Predicted Mean Vote).

As explained in the section 3.3, due to the unavailability of comprehensive hourly weather data of the stations close to Bulwer, the official representative weather data of the climatic zone 1 (Johannesburg) of South African building energy efficiency regulation (SANS 204) was used. In fact, it represents a valuable reference and a good compromise, compared with the climatic conditions of Bulwer, to obtain a significant energetic prediction.

The energetic assessment compared the proposed alternative building typology for the housing scenario in the new residential development area with the traditional RDP detached unit of the existing settlement.

The detached house was simulated with its traditional materials (concrete block walls, profiled metal roof on purlin rafters, aluminium frame with single glazing), the alternative typology units were assessed firstly with the same materials and later with some low cost green improvements (double leaf clay brick walls plastered and thermal insulating ceiling for the upper units with a 40 mm extruded polystyrene board). This was done to evaluate firstly the effect of strategic “no-cost” passive design measures such as different building typology and consequent surface to volume ratio of the units, correct orientation, calibrated window to wall ratio, and later the benefits of additional low-cost green strategies such as thermal insulating ceiling and higher performance wall materials locally available. The data about the energetic performance of the materials used for the analysis (in terms of Thermal Resistance R-value) are included in the chapter 5 that shows the results of the assessment.

The hourly operation of appliances, occupancy rate, lighting and cooking was based on the operational schedules provided by the software for residential occupancy, which were customised to the target group assessed by the study and

their habits, considering a seven-day operation. The schedules are differentiated by rooms to simulate the variable usage of appliances and occupancy of the zones during day and night.

The heating was supposed to be provided by an electrical heater (Coefficient of Performance = 1), in order to simulate a likely condition rather than high energy efficient systems that are not feasible due to the cost constraints, operating to allow the spaces to be heated principally during their occupation. The setpoint temperature was set to 20°C whereas the setback temperature to 12°C. The infiltration rate was set to 0,8 ach/hour, considering the usual poor quality of construction of this kind of houses.

The data regarding materials and construction details, internal gains, systems and appliances operation used for the dynamic building energy and comfort performance analysis are included in the Appendix C.

4.4.4. Cost assessment

Finally, a preliminary cost assessment was done to compare the common practice with the proposed optimised scenario and support the implemented strategies.

Data regarding building components and materials cost for the existing settlement and for the proposed residential development scenario were derived from other RDP housing projects in the Municipality, available literature regarding South African case studies (WSP, 2010), the consultancy of AECOM South Africa (Engineering and Quantity Surveying) and WalkerSmith Architects. The preliminary cost assessment was therefore defined with the crucial assistance of members of the two local mentioned firms, through numerous meetings and revisions.

The cost is assessed as building unit cost and divided into top-structure, external works and municipal engineering services, green implementation.

4.5. Assumptions and limitations

The assumption and limitations of the study concern the following aspects.

Some assumptions were necessary due to the unavailability of certain data at the time of the investigation. For the building dynamic energetic analysis, assumptions had to be made due to the unavailability of comprehensive hourly weather data for the weather stations close to Bulwer. A formal request to the South African Weather Service was submitted to obtain the record of hourly weather data for the station of Shaleburn and Ixopo, but the data about global, diffuse horizontal solar radiation and direct normal radiation were not available. Without this data, it is impossible to create the hourly weather file to run the simulation programme. For this reason, the official representative weather data of the climatic zone 1 of SANS 204 was used as a valuable reference for the analysis.

Some limitations could regard the specificity of the case study. However, despite the peculiarity of the context of Bulwer, the methodological framework adopted in the study, particularly through the participatory approach and the scenario analysis, is intended primarily to promote a holistic and integrated design approach to sustainable low-cost settlements. From this perspective, this framework can be generalised also to different contexts and proposed as a guideline for the design process in order to reach sustainability targets and green implementation for the low-cost subsidised housing sector.

Another limitation could be represented by the sample of thirty households for the survey, which could seem to be limited. However, the selected sample included a large variety of households in terms of number of the members, age and habits (singles; parents with children, babies and sometimes old parents; young couples; young single mothers with children), which was effective to describe the different habits within the community and outline the common criticalities in the settlement. The interviews with the inhabitants confirmed in fact that the most critical aspects emerged from the survey were common and general issues for the entire community.

Finally, the preliminary cost assessment was conducted with regard to the concept design of the settlement, blocks and units, defined within the research. This regarded an early stage of the design phase that would need to be detailed and improved to achieve a comprehensive cost evaluation. Therefore, the preliminary cost assessment should be considered, more than a detailed result in terms of cost comparison, a stimulus to understand that alternative green design strategies could

be feasible compared with the common practice, especially if extending the assessment to the whole settlement, and to promote further research in this sense.

4.6. Summary

The methodology followed an integrated and holistic research and design approach to promote the sustainability in the development projects of low-cost settlements.

A case study of a low cost housing development in the KwaZulu-Natal Province was assessed. The research adopted a bottom-up approach combining participatory methods through a survey and interviews with the local community, and a scenario analysis investigating design alternatives and multi-scale design strategies (i.e. building typology, densification, passive design strategies) assessed by sustainability indicators and supported by experimental methods using dynamic building energy modelling and cost analyses.

The final aim is to investigate how a strategic bottom-up approach and multi-scale green design measures, implemented in South African low-cost housing design process, can potentially achieve environmental and social sustainability targets with economic effectiveness.

CHAPTER 5: RESULTS AND DISCUSSION

5.1. Introduction

The various phases of the research were strictly interdependent, so that the outcomes of each phase affected the subsequent stage of the study. This section describes and discusses the results of each research phase. Together with the research methodology described in the previous chapter, the results of the integrated bottom-up design approach and optimisation process, undertaken through the post-occupancy survey and the scenario analysis, define a framework of good practices that can be intended as a guideline to effectively implement green measures in development projects of low-cost settlements.

5.2. Theoretical study: main findings from the literature review

The main outcomes of the theoretical study based on the critical analysis of the available literature, useful to the research aims and objectives, are summarised in the following tables.

The first Table provides a cross comparison of the current South African policies on the sustainability of low-income housing, marking the criticalities, opportunities and challenges that need to be addressed. SANS 204 was included as a reference for the housing sector, due to the lack of a specific regulation on energy efficiency in low-income houses.

Table 5-1: Criticalities, opportunities and challenges for the South African regulation on the sustainability of low-income housing

	CRITICALITIES	OPPORTUNITIES AND CHALLENGES
ENERGY EFFICIENT BUILDINGS REGULATION (SANS 204 AND SANS 10400-XA)	▪ Lack of link between the new regulation on energy efficiency in buildings and the regulation on low-income housing design or retrofit ▪ No specific requirements for low-income houses ▪ Risk of obsolescence of traditional construction practices, which need to evolve to achieve green targets	▪ Add specific rules for the low-income housing sector, related to the low cost interventions which could achieve a high cost-benefit ratio ▪ New potential job and entrepreneurship opportunities related to the green building technologies and the "green economy" with regard to the low-income housing sector ▪ Need to promote training and education about technical aspects on energy efficient buildings, due to the higher competence requested to developers, designers, builders, construction managers, contractors and public officer charged with control and approval
NATIONAL HOUSING CODE	▪ Provision of general green rules for new low-income settlements and units, without any quantitative prescriptions, risking consequently that these measures are not verifiable and therefore not implemented ▪ Retrofit of low-income houses is not considered, and no specific requirements and intervention criteria are provided	▪ Add specific standards with prescriptive requirements for the green implementation in low-income housing development projects ▪ Plan future programmes, financial and institutional mechanisms for promoting and implementing low-cost green measures and renewable energy technologies also in the low-income settlements

The second Table highlights the main findings and learning that can be acquired from international studies and projects on low-income housing, both from other developing countries and developed world, and transferred to the South African context.

Table 5.2: Main findings from international studies and projects on low-income housing

The case studies from developing countries proved the importance of measures as densification strategy, participatory methods and alternative low-cost technologies. Particularly, a participatory approach during the decisional, design and management phase is indeed a fundamental stage of the sustainable development process in order to guarantee the success of low-income housing initiatives.

The developed world offered examples of integrated social housing development, in which the aesthetic quality of the buildings aimed to strengthen the sense of identity of inhabitants. The selected best practices from Europe demonstrated the effectiveness of a holistic design approach promoting social interactions and energy efficiency and hence favouring the sustainability of the projects. From Canada, innovative scenarios provided different design approaches and challenges, in which reused components from other sectors, as the shipping containers, promoted valid alternatives compared to the common practice. Finally, the Australian social housing selected project demonstrated the great benefits of

sustainable design, also validated by Green Star rating. Passive design strategies and low-cost technologies ensured the energy efficiency of the buildings, the environmental and economic sustainability of the housing developments.

5.3. Results of the post-occupancy survey and field audit

The most relevant results of the survey, field audit and interviews conducted on the households of the existing RDP settlement are summarised as follows. Some examples of questionnaires filled with the answer of the inhabitants during the survey, field audit and interviews are included in the Appendix A.

Figure 5-1: Pictures from the interviews and field audit

About 40% of the houses did not have a separate sleeping place, demonstrating the low housing quality and the poor spatial development of several units. About 80% of the households would have needed more space but they could not afford a formal extension.

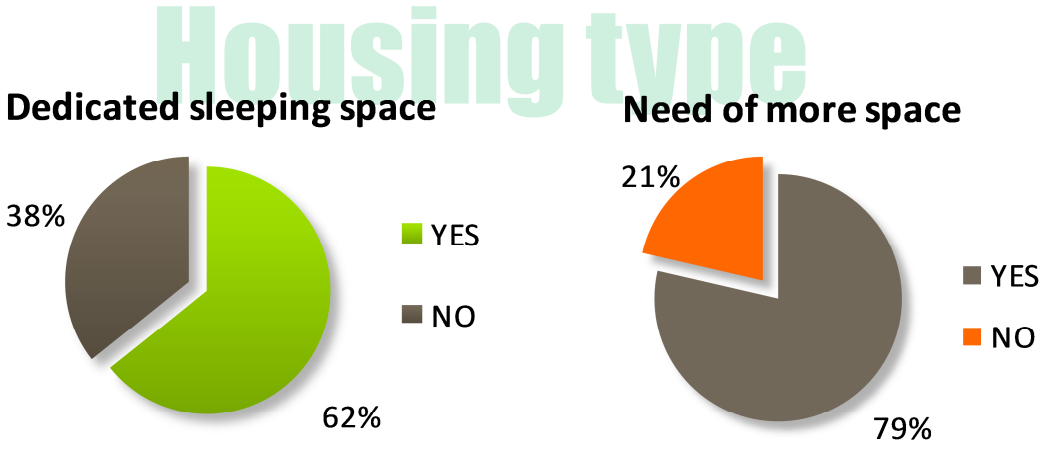


Figure 5-2: Most relevant results of the questions about Demographic Data and Housing Type category

Also, most families experienced problems with the quality of construction such as water leaks through the roof.

These aspects should be considered in the development of new low-cost settlements, because the traditional RDP unit was based on the concept of providing a detached house in its plot also to allow inhabitants to extend their house in the future within the same own plot. Nevertheless, cost constraints has very often made this option not feasible, so that extensions were mostly built as informal additions, without any regulatory control from Local Authorities, in terms of building features, construction requirements, infrastructure and services. Thus, a potential alternative, that was investigated in the subsequent scenario analysis, can be to provide a larger unit, maybe based on a different building typology (for example multi-unit residential building) that allows construction cost savings considering the whole building assessment, in order to invest these savings in a better construction and spatial quality of the units.

About 80% of the households used electricity as primary energy source for domestic uses (monthly cost range for prepaid electricity: R 100-350 (≈ $ 10-35) with peaks of R 500-700), but only 42% had a heater whereas the remaining households used wood or blankets to get warm in the coldest periods. Households used mostly kettles or plot on a stove for heating the water for personal or other domestic uses. 80% of the houses had no ceiling so that no passive design strategy is implemented to mitigate winter climatic conditions. 93% of the interviewed complained very cold indoor winter conditions and 50% also experienced very hot in

the summer inside the houses, 86% of which did not have any fan at least to provide artificial convective ventilation cooling.

The implementation of low-cost passive building design strategies, as correct building orientation, limited surface to volume ratio for each unit, calibrated window to wall ratio, thermal insulating ceiling, solar shading devices, is therefore crucial for this kind of housing, due to the cost-constraints that limit the possibility to use high performance materials and components.

The education of inhabitants is also very important, especially because all the households were definitely interested in a building users' guide, which could help them to use energy efficiently in order to improve living conditions and save operational cost.

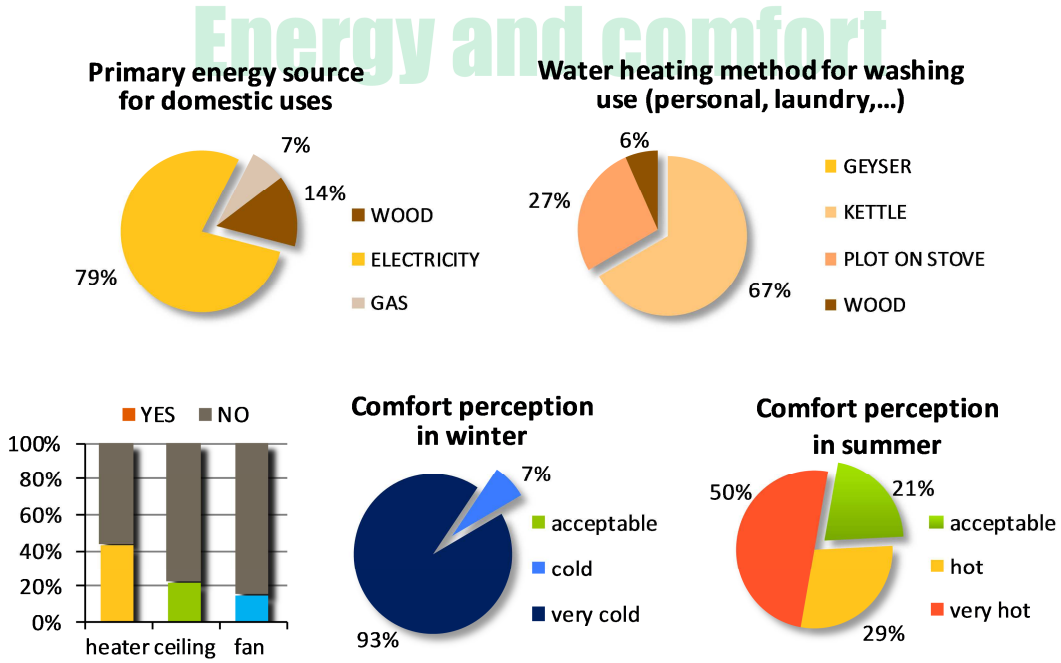


Figure 5-3: Main results of Energy and Comfort categories

All the families got water from a communal tap being the water reticulation not implemented at the time of the investigation. They did not reuse rainwater and only 1/10 of them adopted environmentally responsible behaviour and reused greywater to clean toilet. All the households were interested in a rainwater tank as a possible green implementation and considered it highly beneficial for them.

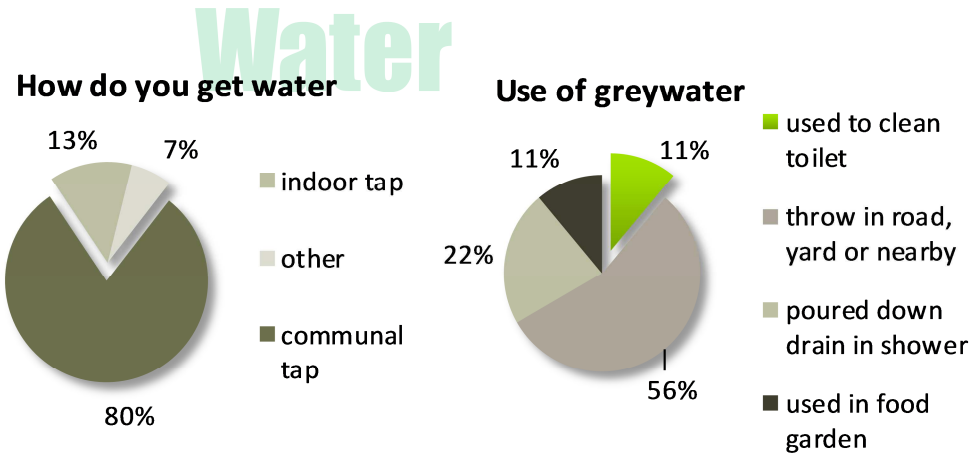


Figure 5-4: Main results of the Water category

All the interviewed complained the lack of any communal areas for social interaction within the settlement. They had to use a unit of a household even to discuss basic problems of the community. 62% of households would have been available and interested in living in multi-unit residential buildings such as blocks with maisonettes or row houses, sharing facilities with neighbours. Low-income communities do not ever easily accept this option, because they usually associate multi-storey buildings to the single quarters hostels or the gangland tenement blocks constructed in the apartheid era. During the survey and interviews, time was hence dedicated to let people understand and explain them the potential advantages of community living and alternative compacted multi-unit typologies. Upon the benefits understood, households showed then their openness to alternative building typologies and subsequent social implications, neighbours and community relations. This outcome demonstrated the importance of the participatory process in terms of education of people, as an instrument capable to promote the transition to medium-high density scenarios and different community living models.

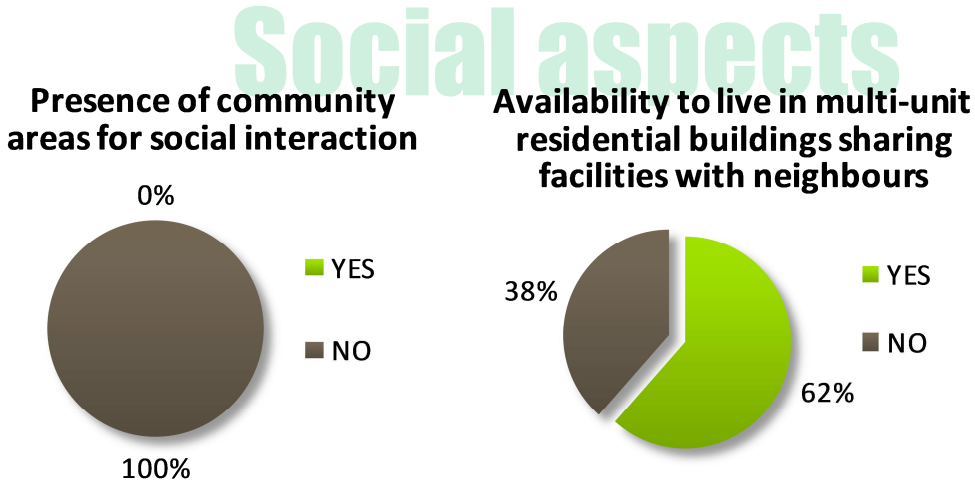


Figure 5-5: Most relevant results regarding social aspects

In terms of food provision and vegetable gardens, half of the households had a private food garden and 79% of the interviewed were interested and available to establish community vegetable gardens to provide secure food to the inhabitants. This demonstrated the positive inhabitants' perception of potential community services as vegetable gardens that can provide benefits to households, foster social interaction and create job opportunities.

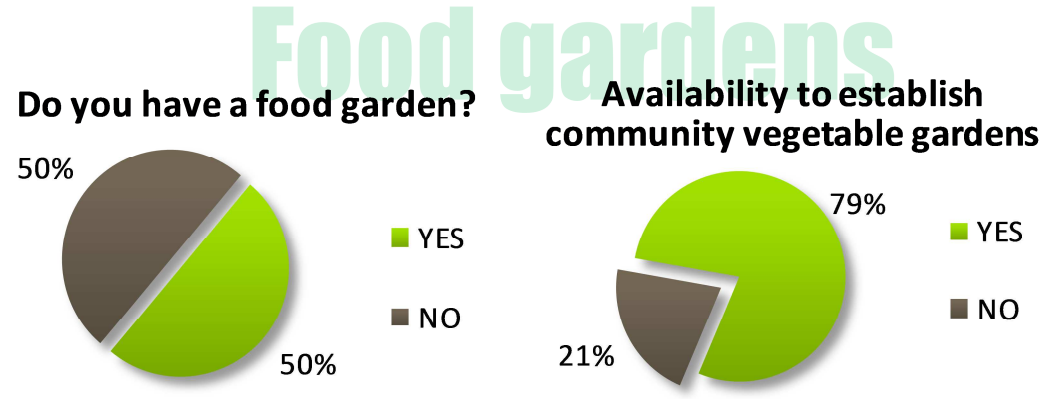


Figure 5-6: Main results of the Food Garden category

The health condition of the households is generally good. In terms of waste collection, inhabitants were available to separate their waste products but preferred them to be collected close to their house. They did not reuse any waste product, but

were interested in being educated on how to reuse some products (i.e. plastic materials) also for entrepreneurship purposes.

The most used transport system is the minibus, and a relevant portion of the income (around 300-400R monthly) is used for that. They did not use bicycle due to the distance of the workplace.

The outcomes of the survey supported the decisional phase for proposing low-cost housing scenarios for a residential development area in Bulwer. Due to the affordability criteria of low income housing, the focus of the study was switched from the assessment of the single house to a broader analysis of the settlement, which included different building typologies and related schemes of land use, community shared services that could also realise cost saving considering the settlement as a whole.

5.4. Scenario analysis

5.4.1. Housing typologies study

As described in the methodology, the aims of the housing typologies study was to explore the potential benefits, in terms of housing quality, functional aspects, environmental and energy impacts, socio-economic implications, achievable through the adoption of alternative building typologies. The housing typology study was structured in six phases and the results are described and commented in this sub-chapter.

The first phase investigated the common South African practice in terms of low-income state subsided housing typology, identified in the single detached unit of 40m^2 of gross floor area. In the common practice, the unit is repeated within the settlement generating a repetitive and anonymous built environment. The unit is usually characterised by low quality of materials and by the absence of creativity in the design of the building envelope. The unit is typically built in the centre of a rectangular private plot, which could be used as a private garden, allowing an extension of the house. As mentioned, the option of formal extension has been rarely implemented due to the cost constraints, resulting in the proliferation of informal additions. This housing typology generates a low-density development.

The following Figure 5-7 illustrates plan and elevation of a typical low-income state subsided unit, while Figure 5-8 shows views of the RDP units in Bulwer.

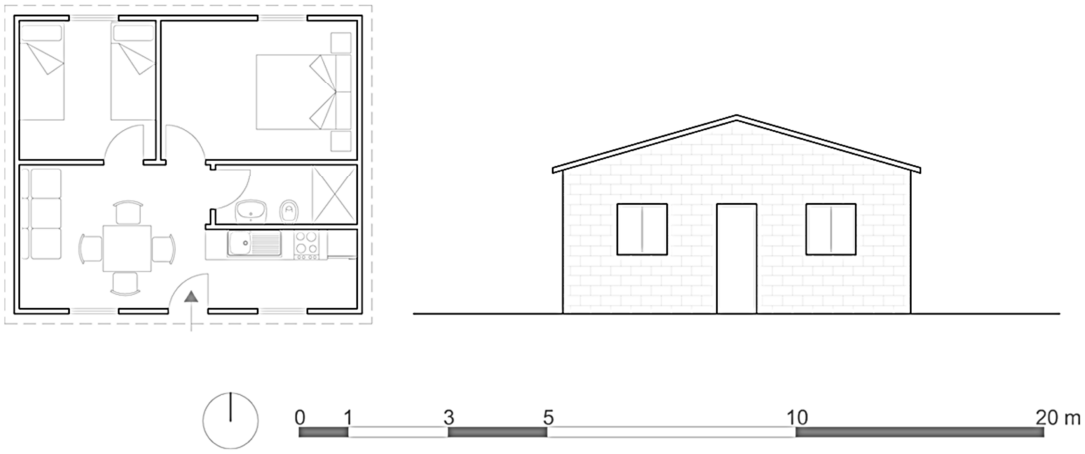


Figure 5-7: Plan and elevation of the detached house

Figure 5-8: Views of the RDP units in Bulwer

Based on the findings from the literature review, the local context and the outcomes of the survey, the study proposed two alternative suitable housing typologies, row house and maisonette, which better responded to the aims of sustainability for the built environment.

These typologies were investigated and a concept design of the building and the units was developed, following environmental criteria and green basic design principles related to the local context (orientation, form, rooms' layout based on solar path, window to wall ratio). This sub-chapter includes some drawings and sketches of the typologies analysed. More detailed CAD drawings and further representative sketches produced during the housing typologies study, both for the common practice and the proposed alternative typologies, are included in the Appendix B.

The row house consisted in a two-storey unit of 47,5 m^2 gross floor area, sharing two walls with the adjacent dwellings. An internal staircase linked the ground floor (living space, kitchen and toilette) to the upper floor (bedrooms). Private front and back gardens would allow limited extension of the unit. Six units composed each block.

When adopted within the densification strategy, the orientation of the block of row houses was defined in the range 0-17 degrees east, in order to favourite winter solar gains and heat radiation in the habitable rooms, preventing at the same time summer overheating. The living areas were north-facing, in order to receive unobstructed winter sun. As the northern side of the building received the most sun, the roof overhang was designed to be longer to provide shading during the hot summer.

The row-house was considered the most acceptable medium-density housing typology.

The following Figures 5-9 and 5-10 show the ground and first floor plans and the South elevation of the designed row housing block.

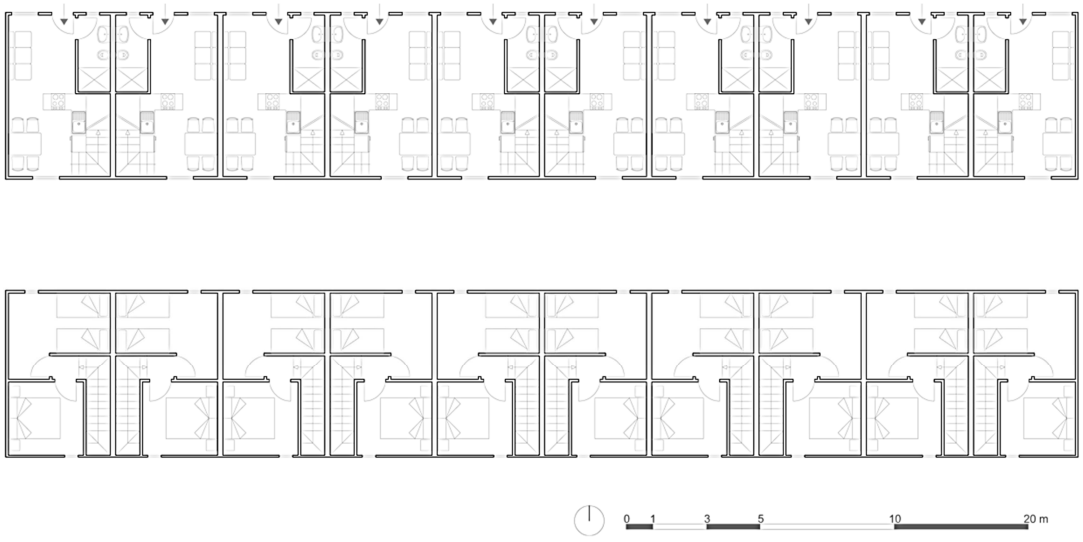


Figure 5-9: Ground floor and first floor plans of the row-houses

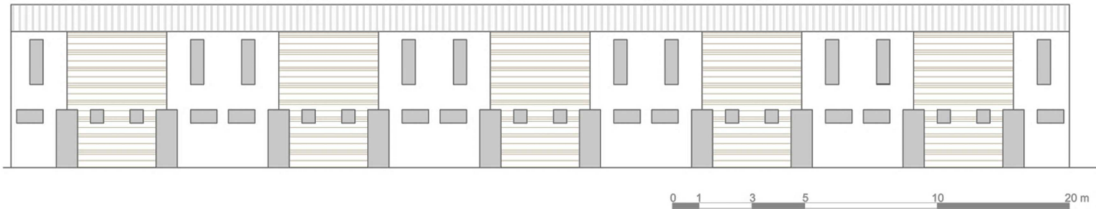


Figure 5-10: North elevation of the row houses

Some Municipalities across South Africa have recently started to consider the row house typology to promote affordable housing developments, for example in the Cornubia Project in Durban and in the Thornhill Ministerial Housing Project in Port Alfred (Figure 5-11).

Figure 5-11: Examples of row houses in South Africa. (Source: DHS, 2013)

The second promoted housing typology was the maisonette. It consisted in a two-storey block with one-storey units. Therefore each unit shared various building components (internal floor, perimetral walls) with adjacent units, reducing therefore the surface to volume ratio of the unit and the heat loss to outside environment. A public green area completed the block that could be used as a space for social interaction and other community uses (for example vegetable gardens). In a first design option of the block, two external staircases allowed the access to the upper units, whose entrance led to a common balcony, acting also as an overhang to shade ground floor units on the Northern side.

Also the layout of the maisonette was based on green basic principles and passive design criteria. This typology promoted medium-high density housing development. Figure 5-12 shows the upper floor plan of the maisonette block with common balcony.

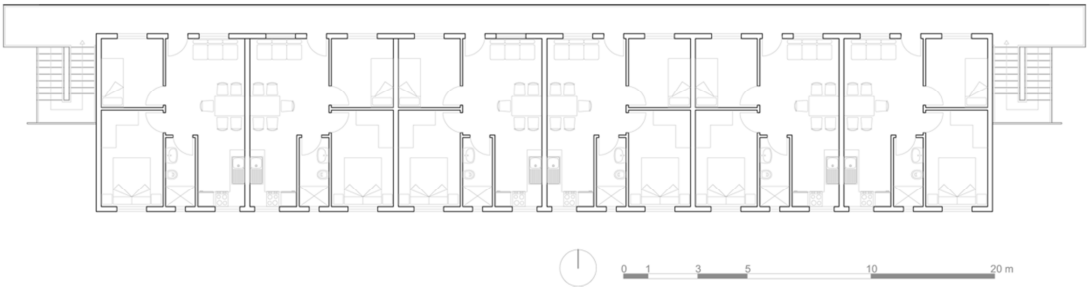


Figure 5-12: Upper floor plan of the maisonette housing typology with common balcony

From the outcomes of various meetings and revisions with the external advisor, Architect Patrick Smith, the maisonette housing typology was refined to improve the safety and privacy levels. Therefore, an improved scheme was elaborated for the local context, introducing an additional external staircase, which reserving one common balcony for each two upper units. Considering the coldness of the climate of Bulwer and the prevalent winter comfort requirement, the balconies were moved on the South façade, in order to allow the maximum solar gain on the North side without any obstruction. Summer overshadowing was thus guaranteed through a wider roof overhang dimensioned by energy simulation software to shade both the windows of upper and ground floor in the hottest period of the year.

Figure 5-13 shows the typical floor plan of the refined design of the maisonette block.

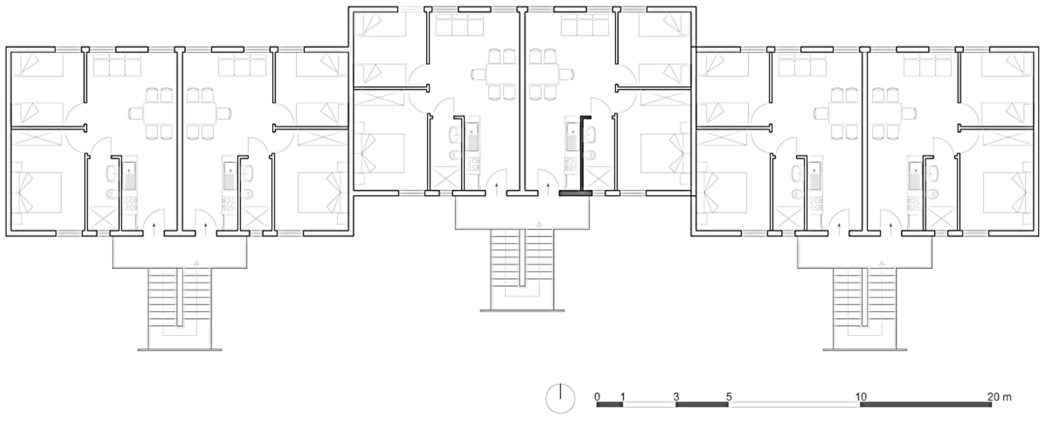


Figure 5-13: Plan of the maisonette housing typology with semi-private external staircase

Figure 5-14 and 5-15 show respectively elevations and 3D sketches of the maisonette housing block.

Figure 5-14: North, South, East and West elevations of the maisonette housing block

Figure 5-15: 3D sketch of the maisonette housing block

A qualitative cross comparison between the existing layout and the two different schemes suitable for the local context was done to investigate advantages and criticalities based on the four impact categories of economy, social implications, energy and environment and safety, described in the methodology chapter. The comparison analysis was done by four grades of evaluation: highly negative, negative, positive and highly positive.

Figure 5-16 illustrates the housing typologies cross comparison framework.

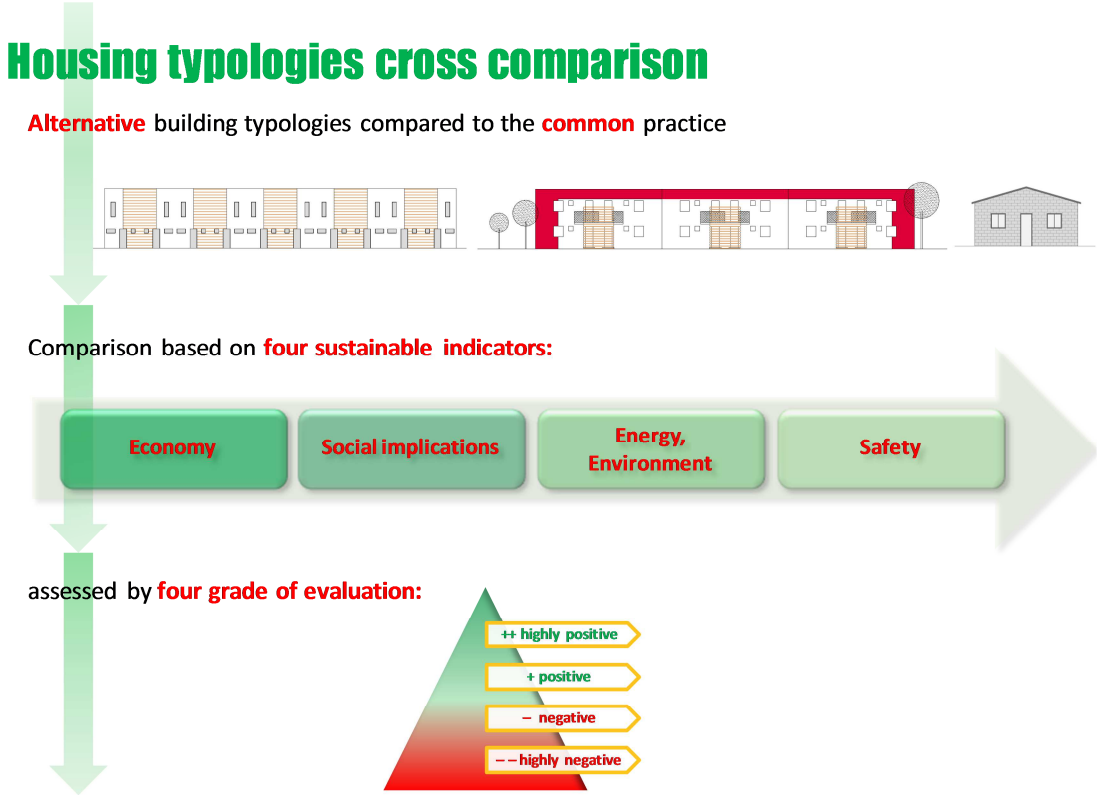


Figure 5-16: Framework of the housing typologies cross comparison

The outcomes of housing typologies cross comparison are summarised in the Matrix of typologies of Table 5-3.

Table 5-3: Matrix of typologies

	Typology 1 - Detached house (Common practice, 1 floor)	Typology 2 - Row house (two-storey units, with private internal stair)	Typology 3 - Maisonette (two-storey building with one floor units, shared gallery each two upper floor units)
Economy	+ No cost for community areas (only private plots) – Max number of building components per house – – Low cost-effective subsidy utilisation – – Maximum land utilisation, bulks and roads areas	++ High cost saving for limited land utilisation, bulks and roads area ++ Most suitable to slope terrain + Medium cost saving due to shared building walls + Efficient subsidy utilization – Cost for public areas external works – – High cost for internal stair (one per unit)	++ High cost saving for limited land utilisation, bulks and roads area ++ High cost saving due to maximum number of shared building components (walls, stairs) + Suitable to slope terrain + Efficient subsidy utilization – Cost for public areas external works – Cost for shared external stairs and balconies
Social implications	++ Maximum potential extension of the house ++ Better sense of privacy – – No community areas – – Low social interaction	++ Community areas for social interaction + Potential of job creation in the community areas (i.e. vegetable gardens, gardening) + Limited potential extension of the house – Diminished privacy	++ Community areas for social interaction ++ High level of social integration at building level + Potential of job creation in the community areas (i.e. vegetable gardens, gardening) + Sense of communal/shared space – – No potential extension of the houses – – Low privacy
Energy, Environment	– – High surface area to volume ratio (S/V = 1,30/m) – – No potential shared shading systems – – High land utilisation	+ + Low surface area to volume ratio of the unit (S/V = 0,71/m) + Medium potential use of trees in public areas as shading devices (medium density typology) + Low land utilization	++ Low surface area to volume ratio of the unit (S/V = 0,69/m) ++ Potential shading system using the external shared stairs and balcony (in hot climate) ++ High potential use of trees in public areas as shading devices (medium/high density typology) + Low land utilisation
Safety	– – Poor visibility to the surroundings – – Poor surveillance and security	+ Good visibility + Good surveillance and security	++ Best surveillance and security ++ Best visibility from the balcony – Shared balcony with the neighbours at the upper floor

The detached typology negatively affects most categories, especially in terms of environmental and safety aspects. In fact, the high surface area to volume ratio (S/V = 1,30/m) and the high land utilisations did not favourite energy efficiency and environmental sustainability. In addition, the poor visibility to the surroundings that does not allow good surveillance caused inadequate levels of safety. The economic implications were negatively affected as well. The absence of shared building components increase construction cost and consequently the subsidy utilisation resulted low effective. The maximum potential extension of the house and the better sense of privacy guaranteed through the detached unit were considered the only advantages of this typology.

The row house and maisonette schemes are instead promoter of medium density, cost and energy saving and community interaction.

The two storeys units of the row house typology would guarantee discreet visibility, improving the level of security and surveillance. The communal living model promoted by the row house block would foster the creation of a sense of community, for example by the collaboration for the maintenance of the block. The row house would ensure high cost saving for the limited land utilisation, bulks and roads area, and medium cost saving due to limited number of building components being partially shared. On the other hand, the cost related to the public areas and cost for internal stairs (one per unit) indicated the row house as probably more expensive than the maisonette.

The maisonette would achieve many advantages related to the cost saving for building construction and maintenance, due to the large number of shared building components. The limited land utilisation would also imply reduced cost for infrastructure. In comparison to the row house, considering the same gross floor area of the block, the maisonette would allow a larger net area for the units that could be used for habitable spaces (being absent the internal staircase). The more numerous communal spaces could also improve the sense of community and the sense of public space. The communal and public spaces would promote high level of social interaction and potential of job creation in the community areas (i.e. vegetable gardens, gardening). The maisonette would positively respond to energetic and environmental sustainability, considering the limited land usage (medium-high density typology), the higher surface to volume ratio of the internal

unit and the potential shading system represented by the external shared stairs and balcony, useful especially in hot climate.

The results of the matrix suggested a maisonette typology predominance development for the proposed scenario that could reach highest benefits for the aim of the study, considering especially the greater potential of social interaction, the economic saving due limited number of building components and municipal engineering services, and the positive environmental and energetic implications.

5.4.1.1. The proposed typology for a potential low-income housing development in Bulwer: the maisonette

The maisonette typology was therefore deeply investigated, developing a more advanced design of the potential scenario of low-cost settlement development.

Each two-storey block comprised 6 units of 47,50 m^2 gross floor area per floor. The layout plan of each house is designed to be climatic sensitive to the local context, in terms of orientation, distribution of zones and window to wall ratio. Windows were parametrically calibrated to the opposite facing sides through energy simulations to maximise heat gains on the northern side (avoiding summer overheating, through the roof overhang providing shading) and reduce heat loss on the south facade.

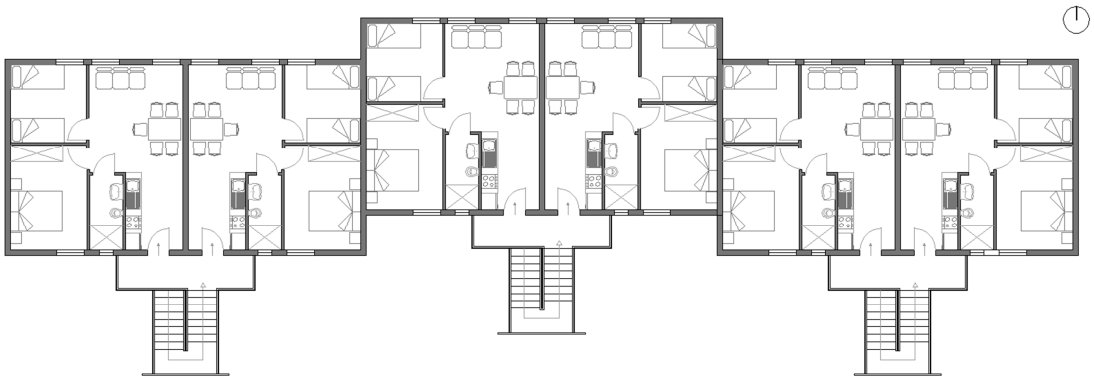


Figure 5-17: Plan of the proposed maisonette housing typology

The best orientation of the blocks for the Bulwer climate condition was chosen, achieving solar gain during the winter season and reducing the overheating in summer for the living and sleeping areas. The following Figures show some render images of the proposed maisonette block.

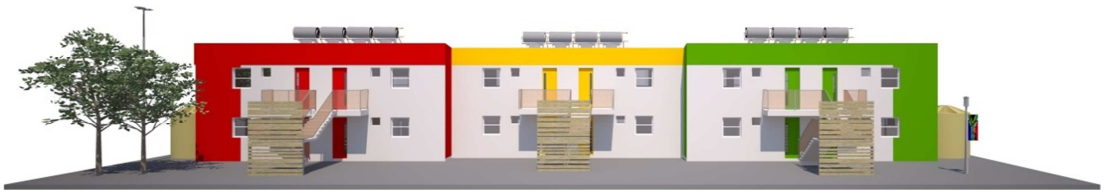


Figure 5-18: Southern view of the proposed maisonette block

Figure 5-19: 3D view of the proposed maisonette block

Figure 5-20: 3D view of the proposed maisonette block

Figure 5-21: 3D view of the proposed maisonette block

5.4.2. Densification strategy

The medium and medium-high density typologies were used to investigate the benefits of a densification strategy, especially regarding the number units and people allocable, reduced land use, reduced extent of engineering services due to the more aggregate layout of the settlement.

Figure 5-22 illustrates the three stages that articulated the analysis focused on the densification strategy.

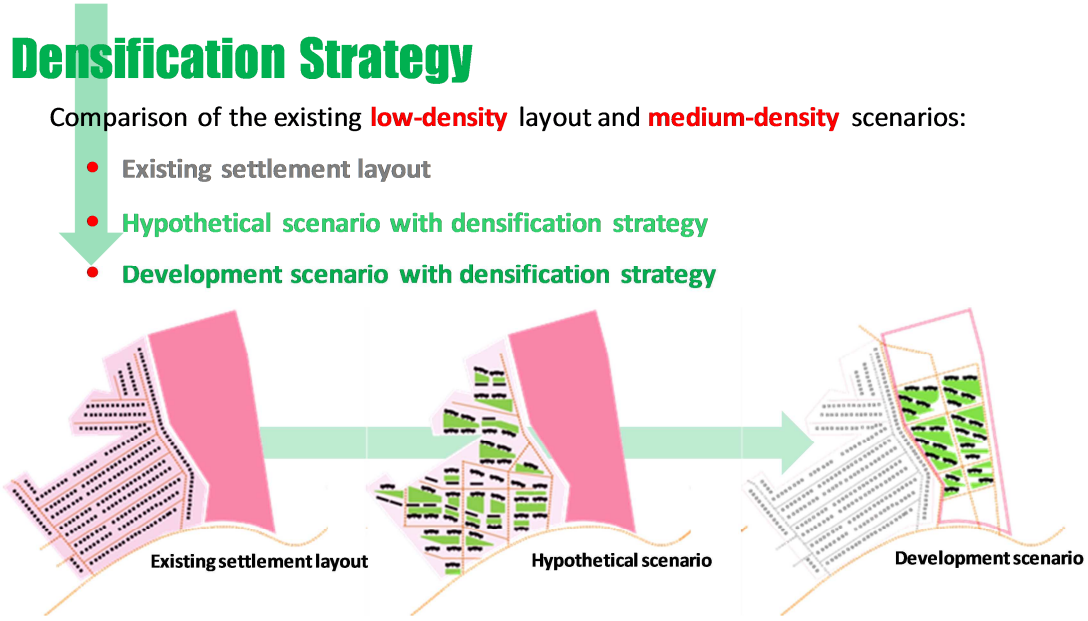


Figure 5-22: Stages of the analysis related to the densification strategy

The investigation of the existing layout, based on available information and maps from the Urban Regeneration Plan of Bulwer, orthophotos, cad drawings and the outcome from the site visit, identified the issues related to the existing RDP settlement and the challenges for a hypothetical higher density development.

Firstly, the extent of the low-density layout (12,7 hectares allocating 313 units) caused too long way between different points of the settlement, that prevented social interaction and the creation of a sense of community.

Figure 5-23 shows a layout scheme of the existing RDP settlement in Bulwer, in which the main roads and the 313 units are identified.

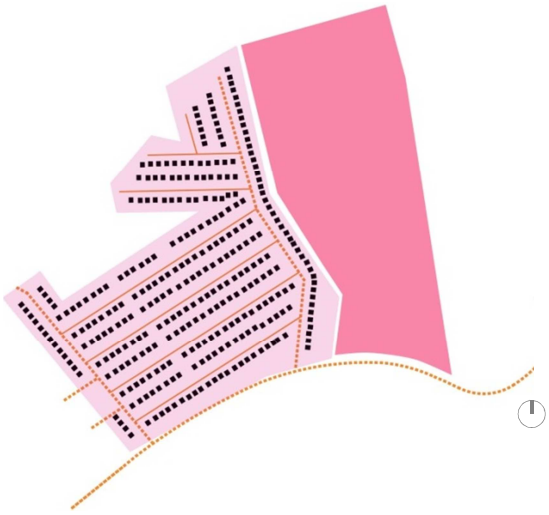


Figure 5-23: Layout scheme of the existing RDP settlement in Bulwer

The results of the first stage of analysis were confirmed during the site visit, in which it was possible to observe the effect of the low-density development on the community's perception, investigated also through the survey. The settlement seemed weak in terms of facilities, communal services for the community and social interaction of inhabitants. This was also prevented by the absence of pavements, kerbs and street lighting systems.

The subsequent analysis compared the existing low-density layout with medium-density scenarios, firstly studied as hypothetical scenario (Figure 5.24) in the same area of the existing settlement to investigate the densification potential. This hypothetical scenario was based on the combination of maisonette and row house typologies, evaluating the increase of allocable households within the boundary of the existing settlement.

The proposed hypothetical scenario could have allocated in the same area double number of units than the existing layout (Table 5.4). A significant reduction in terms of roads area was also registered, that would have translated in cost saving for the engineering services. From this perspective, the increase of population allocated and population density and the reduced extent of roads and engineering services demonstrated the benefits of a hypothetical densification strategy.

Figure 5-24: Hypothetical scenario layout scheme with densification strategy

The densification strategy was hence applied to the residential development area defined by the Bulwer Regeneration Plan (Figure 5-25). The layout was based on the maisonette layout to minimise the land occupied and promote a medium-high density development. For allocating the same number of units of the existing settlement, this scenario would use less than half land area, demonstrating the high benefits in terms of gross density, population density, potential social interaction, cost saving due to the reduced extent of municipal engineering services.

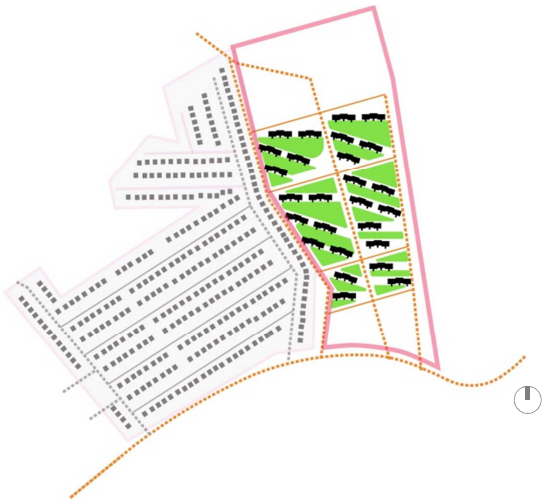


Figure 5-25: Development scenario layout scheme with densification strategy

Table 5-4 shows the results of the analysis of the densification strategy comparing the different scenarios (existing, hypothetical and development scenarios), in order to appreciate the respective benefits.

Table 5-4: Density indicators for the existing settlement, hypothetical and development scenarios

	Existing settlement layout	Hypothetical scenario with densification strategy (same land area)	Development scenario with densification strategy
Land area occupied [ha]	12,7	12,7	5,4
Number of units	313	660	312
Unit gross area [m^2]	40	47,5	47,5
Gross density (n. of units/land area) [n. units/ha]	24,6	52	57,8
Roads area [ha]	1,6	1,3	0,8
Population allocated (5 people per household) [n. people]	1565	3300	1560
Population density = n. people / land area [n. people /ha]	123,2	259,8	288,9

The layout of the development scenario of the new settlement was based on environmental and climatic considerations for the local context, using preliminary qualitative energetic assessments (i.e. overshadowing analysis) to define appropriate distance of blocks to maximise winter solar gains for each units and strategise the more suitable location for community areas and food gardens (Figure 5-26).

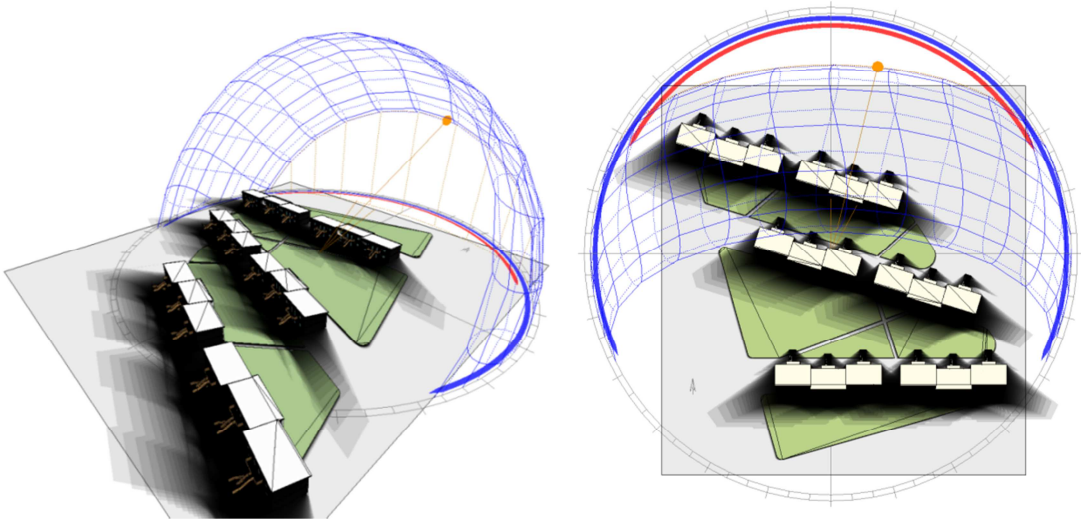


Figure 5-26: Shadow range analysis in the winter solstice of a typical district of the proposed development scenario

The communal vegetable gardens were considered as a crucial strategy for the human settlement development and a potential resource in terms of food cultivation and security, job creation, social integration and collaboration.

Figure 5-27 shows the design phases and criteria for the definition of the layout of the new settlement related to the development scenario.

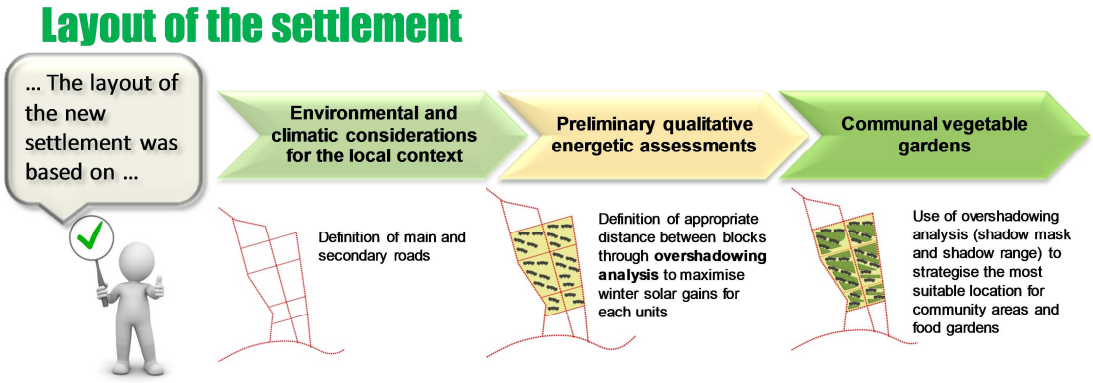


Figure 5-27: Design criteria for the definition of the layout of the new settlement (development scenario)

Figure 5-28 represents an artist impression of the proposed low-income development scenario in Bulwer.

Figure 5-28: Artist impression of the designed low-income development scenario in Bulwer

The benefits achievable through the applied densification strategy and the proposed development scenario are summarised with regard to the following aspects:

- *Limited use of land*: In the promoted development scenario, the use of land was limited due to the allocation of households in more aggregate alternative housing typologies. Communal vegetable gardens were also inserted in order to improve the social aspects of the community.
- *Travel distance and transportation*: The limited extent of the internal roads would reduce the distances within the settlement, favouring a closer social interaction between inhabitants.
- *Cost of infrastructure:* The compact layout would reduce the extent of roads, municipal engineering services and related cost.
- *Socio-economic implication*: Communal areas and vegetable gardens within the settlement could potentially improve the social interaction of inhabitants, health through the production of secure food, and could promote job opportunities related to the management of the community gardens or the establishment of other jobs related to the local culture. For example, the communal areas could contain trade and exhibition activities of local handicraft, creating an entrepreneurship of the local culture and art that could be linked to the touristic programmes of Municipalities. These programmes could foster the entrepreneurship of traditional culture through the organisation of site visits, aimed also at promoting and exhibiting a new model of sustainable development of the low-income subsidised settlements.

The development scenario implementing the multi-scale green strategies (typology, densification, passive design low-cost strategies and green implementation) was finally investigated in terms of construction cost. The results of the preliminary cost assessment and cost comparison of the proposed scenario and the traditional practice are discussed in the sub-chapter 5.6.

5.4.3. Dynamic building energy and comfort performance analysis

Detailed dynamic energy simulations through the software DesignBuilder/EnergyPlus were conducted on the proposed densification housing development scenario in order to compare it with the existing settlement.

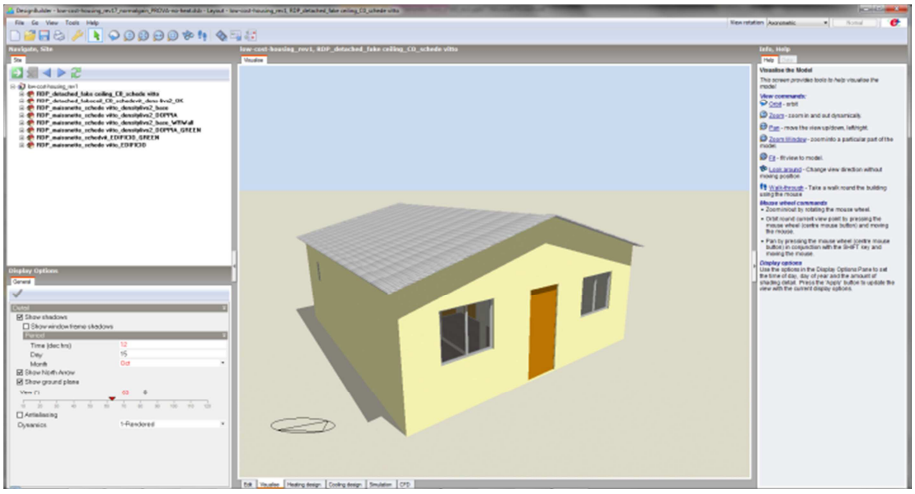


Figure 5-29: View of the model of the traditional detached RDP unit within the dynamic energy simulation software

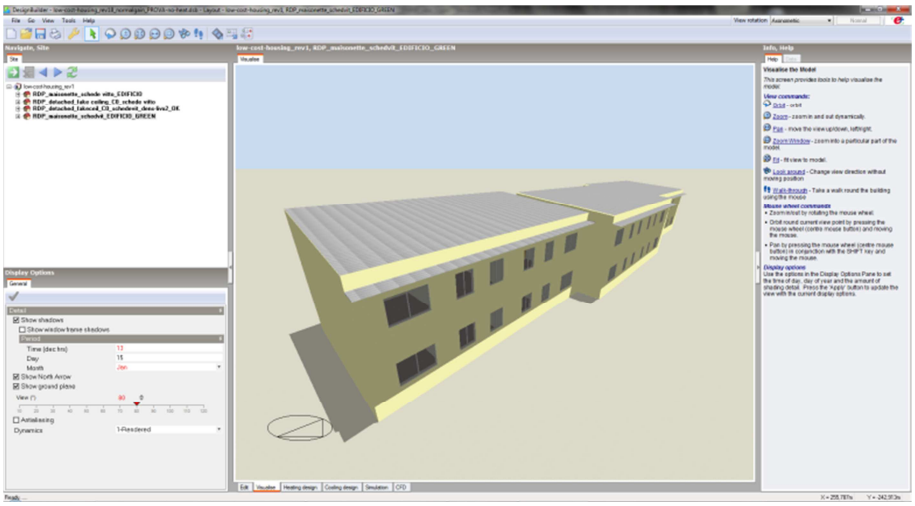


Figure 5-30: Perspective view of the model of the Maisonette building within the dynamic energy simulation software

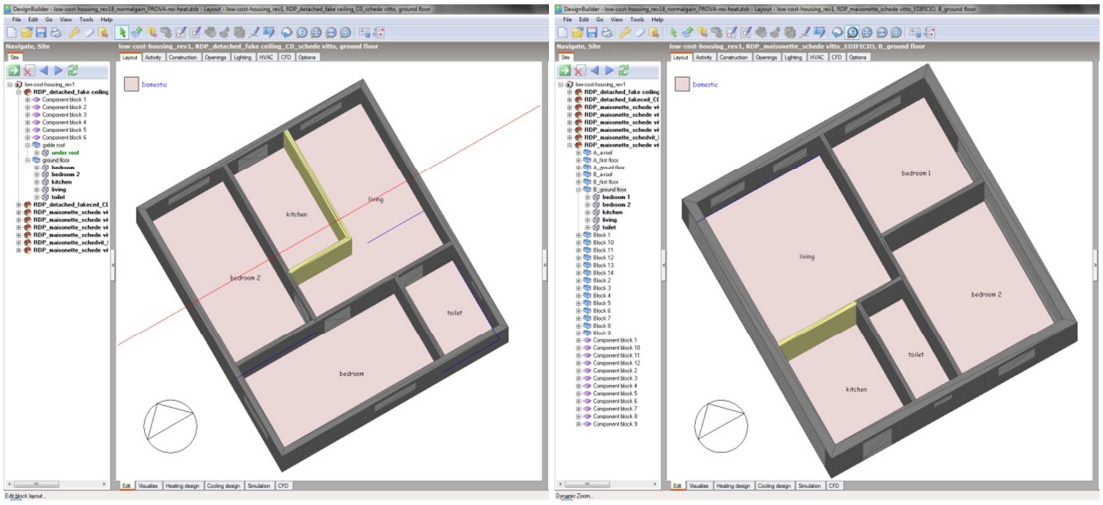


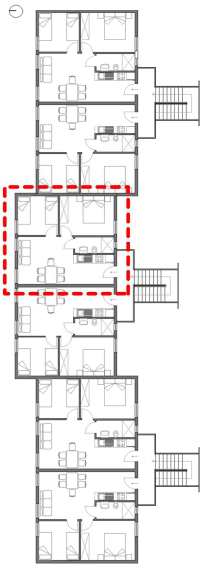
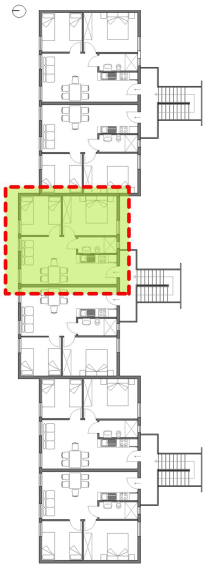
Figure 5-31: Axonometric view of the spatial development of the detached unit (left) and the maisonette unit (right) used within the dynamic building energetic simulation software

As explained in the methodology, the aim was firstly to evaluate the effect of green passive design measures such as densification criteria, alternative building typologies and subsequent different surface to volume ratio of the unit, correct orientation and layout of housing spaces, calibrated window to wall ratio. Secondly, additional strategic low-cost green strategies, such as thermal insulating ceiling and higher performance wall materials locally available, were added to the model of the optimised scenario. The assessment led to a quantitative investigation of potential benefits of the mentioned strategies in terms of heating energy consumption (KWh) and indoor comfort (using the Predicted Mean Vote index), being the winter comfort requirements the most critical for the local context.

These benefits were compared with the common practice represented by the detached house scheme of the existing RDP settlement. Traditional RDP houses are in fact high energy inefficient not only due to the cost constraints, but especially because they are built without any consideration of basic green design principles.

The methodology section explained the criteria and assumptions made to define operational schedules of appliances, occupancy rates, heating system. The detached unit was assessed only with traditional materials, whereas the maisonette unit was evaluated also with few strategic additional green improvements. The following table describes the materials used for the energy and comfort assessment and the respective energetic performance in terms of thermal resistance R-value (m^2 K/W):

Table 5.5: Materials and building components used for the dynamic energy assessment

TYPOLOGY		WALLS	ROOF	GROUND/ INTERNAL FLOOR	WINDOWS	CEILING
RDP detached unit		concrete block +plaster (R = 0,42 m² K/W)	profiled metal roof on purlin rafters (R = 0,14 m² K/W)	mass concrete surface bed (R = 0,41 m² K/W)	aluminium frame with single glazing	-
Maisonette unit		concrete block +plaster (R = 0,42 m² K/W)	profiled metal roof on purlin rafters (R = 0,14 m² K/W)	mass concrete surface bed (R = 0,41 m² K/W)	aluminium frame with single glazing	-
Maisonette unit + low cost green construction strategies		**Double leaf clay brick + plaster (R = 0,540 m² K/W)**	profiled metal roof on purlin rafters (R = 0,140 m² K/W)	mass concrete surface bed (R = 0,414 m² K/W)	aluminium frame with single glazing	**4 cm expanded polystyrene panel (R = 1,413 m² K/W)**

The simulation of the maisonette units was conducted in the worst condition, assuming that only the unit assessed was heated whereas all the other units, including the adjacent ones, were considered with free running temperature with only internal and solar gains. This condition is in fact quite likely for a hypothetical low-income multi-unit residential typology.

Also in this extreme condition, the results of the analysis (Figure 5-32) showed that just the alternative maisonette typology, characterised by a lower surface area to volume ratio, and the green design principles of correct orientation and calibrated window to wall ratio, allow for a reduction of the heating energy consumption of 550-650 kWh (depending on the maisonette unit) compared with the detached typology. The benefits are confirmed also in terms of improved comfort: the Predicted Mean Vote values (Figure 5-33) in the maisonette units are in fact definitely closer to acceptable range than in the detached unit, especially in the coldest period of the day (night time).

The two additional construction green implementations (thermal insulating ceiling and double leaf claybrick wall) produced a further relevant reduction of heating consumption, especially in the upper floor unit in which the ceiling is highly effective. The upper unit with the additional green construction strategies resulted in fact in a further energy saving of 48% compared with the traditional construction assumption. The improvement of indoor comfort conditions were also related to the effect of the higher thermal inertia of the double leaf clay brick wall, that allowed to better modulate and contain the fluctuation of the external temperature, stabilising and improving the indoor temperature.

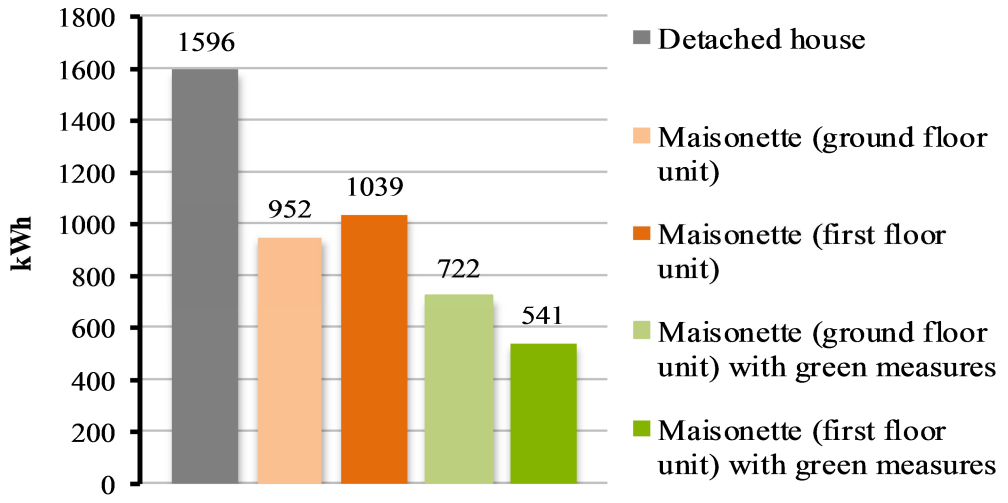


Figure 5-32: Annual heating consumption of the detached unit and the maisonette (ground and first floor units, without and with additional green construction measures)

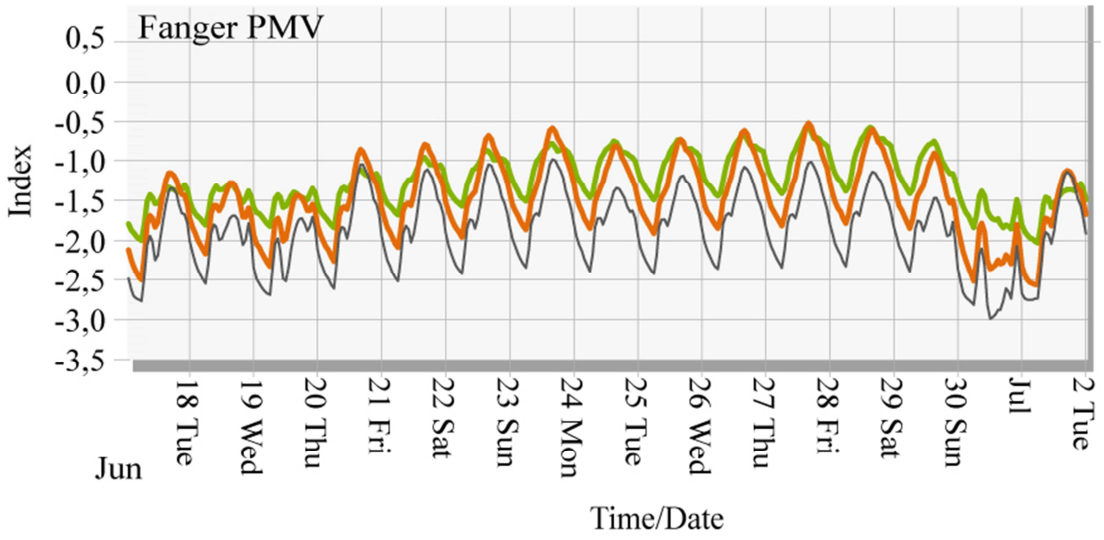


Figure 5-33: Predicted Mean Vote for the detached house and the maisonette first floor unit (without and with green construction measure) in two representative winter weeks (refer to previous figure for the legend of colours)

The dynamic energetic analysis thus confirmed the potential benefits for households, in terms of energy saving and improved indoor comfort of the units, of the proposed development scenario, based on alternative building typology, densification strategies and passive design principles. Few additional strategic low-cost construction green implementations can produce further significant benefits for the indoor environmental quality and energy saving.

5.4.4. Cost assessment

Finally, a preliminary cost comparison assessment was conducted in order to uderstand the economic implications of the adopted densification strategy and green implementation.

The adoption of the alternative building typology together with densification strategies can produce cost saving due to the shared building components between units and limited municipal engineering services (roads, water, sewer and electrical reticulation, etc.).

These savings were considered to be invested in strategic low-cost construction green measures for each unit (thermal insulating ceiling, improved thermal properties material for walls), further green implementation for the blocks (i.e. rainwater harvesting, solar water heating) and for the settlement (vegetable gardens, external works and vegetation for communal areas).

This optimised green scenario could allow for a better quality of houses, including green features that could improve quality of life of the community. Figure 5-34 shows that the scenario would imply a higher total cost per unit (top structure + external work + green implementation) of only about 3% compared with the detached house layout. However, it would use more effectively the subsidy given by the government (R 64.666,00 (≈ $ 6.100,00) for top structure, considering also R 25.696,00 (≈ $ 2.400,00) for municipal engineering services) to provide an improved quality of living, a better built and community environment for low-income communities.

The expanded cost analysis of the common practice and the proposed green potential scenario is included in the Appendix D.

Figure 5-34: Preliminary cost comparison of the detached unit representing the existing low-density settlement and the maisonette unit of the medium density optimised green development scenario

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This research investigated how the implementation of strategic multi-scale green design measures, supported by a bottom-up approach, can potentially contribute to lead low-cost housing sector toward sustainable living targets, combining environmental and social benefits with economic effectiveness.

A comprehensive literature review on South African low-income housing, related policies, best practices from other developing countries and developed world, contributed to understand best practices and innovative green solutions adopted in different context, and to identify the criticalities and the main gaps to be addressed in the South African context

Assessing the case study of a low-cost RDP settlement in the town of Bulwer, the study also experimented a participative approach to the sustainable design, whose strategies were firstly based on the needs expressed by the local community.

Strategic low-cost green strategies implemented at various scales (settlement, building, unit, materials) were hence assessed through a scenario analysis of a potential low-cost housing development in Bulwer, demonstrating the potential benefits in terms of environmental, energetic, social and economic sustainability.

The use of experimental building dynamic energetic simulations allowed for quantifying the implications of aggregate building typologies and strategic low-cost passive criteria in terms of energy saving and comfort. The reduced energy demand and improved indoor comfort of the low-cost units due to the implementation of the proposed green strategies proved the effectiveness of the integrated and holistic design approach experimented with this study.

Furthermore, increasing the energy efficiency of the low-cost settlements could contribute to reduce the dependence from fossil and imported energy, hence enabling a more feasible transition to future energy self-sufficient green infrastructure based on renewable sources.

The results of the study demonstrated the potential benefits for households and whole community of multi-scale green strategies that combine densification criteria, alternative building typologies, passive design measures and social aims, showing that it is possible to provide higher quality low-cost housing with affordable solutions.

The proposed approach and green strategies represent a methodological framework that could support decision making, planning and design phase of future initiatives of sustainable low cost housing development in South Africa. Therefore, the framework can be adopted as a methodological guideline oriented to promote a sustainable design approach and implement green measures in the low-cost housing sector.

The main conclusions can be therefore summarised in the following bullet points:

- ✓ The results demonstrated the importance of a participatory process as a decision-making tool oriented to base the design choices on the actual needs of final users/inhabitants and as educational instrument able to favourite the transition for households toward medium-high density scenarios and different community living models.
- ✓ The research demonstrated that some additional strategic green construction strategies, as thermal insulating ceiling, can provide relevant benefits to the indoor comfort and the energetic behaviour of low-cost units.
- ✓ Nevertheless, before investing in construction measures and higher material quality, it is imperative firstly to adopt a green integrated approach to the design of the settlements, buildings and units. The focus should be primarily oriented to “no-cost” or “very low-cost” green passive design strategies such as correct orientation, window to wall ratio, surface to volume ratio through alternative typology. The study demonstrated, in fact, the potential benefits of this necessary first step of the design to achieve sustainability targets. Through advanced thermal modelling analyses it was proved the effectiveness, in terms of energy saving and indoor comfort, of these green passive design strategies, which primarily depend on an integrated sustainable design approach.
- ✓ Alternative housing typologies, as the maisonette units proposed in the optimised development scenario, could reach higher benefits compared to the common practice represented by the detached single-storey unit, considering especially the greater potential of social

interaction, the positive environmental and energetic implications, and the cost saving.

- ✓ The application of densification strategies for the development of new settlements could guarantee a reduction of its environmental impact, a fostered social interaction and cost saving, especially due to the reduced extent of municipal engineering services. The cost saving could be invested in additional green implementation at the level of the settlement, buildings and single unit, to improve the environmental and energy behaviour of the settlement and the quality of life of the community.

- ✓ As learned from international best practices, the aesthetic quality of buildings, not necessarily costly but just smartly thought, could contribute to create a sense of identity and community for the inhabitants, rejecting the usually monotonous and static environment of settlements generated by the anonymous repetition of units within the site.

Finally, from the outcomes of the research some recommendations for future research could include:

- ⊙ The implementation of green design multi-scale strategies should be implemented by Municipalities through pilot and demonstration projects of entire settlements, tested and monitored in in the long term post-construction and post-occupancy phase, to appreciate the benefits for the community and therefore define one-stop solutions to be repeated as successful models.

- ⊙ The involvement of local communities from the very beginning of the process must be considered as the starting point of an integrated approach to the sustainability of low-cost housing developments.

- ⊙ The outcomes of the study also suggested possible scenarios of redistribution of the national subsidy, favouring higher quality top structure of the houses, including some strategic low-cost green features, while limiting the cost of municipal engineering services through alternative building typologies and densification criteria. From

this perspective, green low-cost housing developments could become attractive in terms of the economic sustainability for private investors due to the potential access to Clean Development Mechanisms.

- Communal areas and vegetable gardens are strongly recommended, especially in a densification scenario, to improve the social interaction of inhabitants, health through the production of secure food, and job opportunities related to the management of the community gardens and other potential businesses. The communal areas could contain trade activities and exhibitions of local handicraft, creating an entrepreneurship of the local culture and art that could be linked to the touristic programmes of Municipalities. These programmes could foster the entrepreneurship of traditional culture through the organisation of site visits aimed also at promoting and exhibiting new models of sustainable development of the low-income subsidised settlements. Also in this case, the education and the engagement of local communities to the decision making is a critical step of the process.

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APPENDICES

APPENDIX A: EXAMPLES OF THE QUESTIONNAIRES FILLED WITH THE ANSWERS FROM THE INHABITANTS OF THE EXISTING RDP SETTLEMENT IN BULWER

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

1. HOUSEHOLD DEMOGRAPHIC DATA AND HOUSING TYPE

House N°:	378	N° of adults:	2	N° of children :	1
Number of years lived here:	2	Are you the owner or a renter?	OWNER ✓	RENTER	
How many rooms do you have?	4	Do you have dedicated sleeping space?	YES ✓	NO	
Are there existing formal extensions?	YES ✓	NO	Are there existing informal extensions/outhouses?	YES	NO ✓
		Are you planning to extend your house?	YES ✓	NO	

What did you live in before moving here?	ROOM	BRICK HOUSE ✓	BACKYARD	INFORMAL SETTLEMENT	CAR	CARAVAN	TENT

Why did you decide to live here?	WANTED A PLACE OF MY OWN	NEEDED MORE SPACE	EXPERIENCED CONFLICT WITH PEOPLE LIVING WITH ME	COULD NOT AFFORD RENT	EVICTED BY LANDLORD	WANTED TO BE CLOSER TO WORK ✓

2. ENERGY (HEATING, COOLING, COOKING, WATER HEATING, LIGHTING)

Approximately how much do you pay for electricity monthly?	R120	What kind of electricity meter do you have?	PREPAID ✓	ACCOUNT

Where do you get electricity from?	OWN ELECTRICITY BOX	ELECTRICITY POLES	NEIGHBOURS ✓

What energy sources do you use for space heating?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY ✓
What energy sources do you use for preparing meals?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY ✓

What cooking, heating and cooling appliances are being used in the house?	2 PLATE STOVE ~~✓~~	MICROWAVE	HEATER ~~✓~~	KETTLE ~~✓~~	FAN	FRIDGE	OVEN

Do you use a wonderbag for preparing meals?	YES ~~✓~~	NO ~~✓~~		
Do you use a heater to keep warm in winter?	YES ~~✓~~	NO	Is there a ceiling?	YES ✓ NO
Do you use a fan to cool your house in summer?	YES ~~✓~~	NO		

How do you heat up water for washing (personal, laundry, dishes)?	GEYSER	KETTLE ✓	PLOT ON STOVE	OTHER

How many times a day do you heat up water with a kettle/on stove?	30 ?	How many litres do you heat up each time?	2L

How many light fittings are being used in main house?	N° OF STANDARD INCANDESCENT:		N° OF COMPACT FLUORESCENT:	4

Would the owner /resident be interested in a building user's guide that teaches how to save energy in your house?	YES ✓	NO

3. WATER, PLUMBING FACILITIES AND RAINWATER

Approximately how much do you pay for water monthly?	R300	Is there a water meter?	YES ✓	NO

Do you use the communal standpipe for any of your water needs?	YES ✓	NO	How do you get water?	INDOOR TAP ✓	OUTDOOR TAP	COMMUNAL TAP	NEIGHBOUR

Is there any property leaks?	YES	NO ✓

What bathroom facilities are there in your house?	TOILET ✓	SHOWER ✓	BATH	BASIN

What is happening to greywater after washing dishes or clothes??	HAVE A SINK CONNECTED TO THE SEWER	THROW IN ROAD, YARD OR NEARBY	POURED DOWN DRAIN IN SHOWER ✓	USED IN FOOD GARDEN

Would you be interested in a rainwater tank for backup water supply and for a food garden?	YES ✓	NO

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

4. EMPLOYMENT, PARTICIPATION AND SOCIAL INTERACTION

N° of people in household with:	FORMAL JOBS: N°		INFORMAL WORKS: N°		SMALL BUSINESSES: N°		GRANT INCOME N°	

Approximate combined household	R ___	Would you be interested in expressing your needs to the designers and the Municipality before they build your house?	YES	NO	Would you have been available to live in multi-unit residential buildings (i.e. maisonette/rowhouses)?	YES	NO

Would you be interested in being engaged in the construction of your house?	YES	NO	Would you be interested in learning green jobs (i.e. water harvesting installations)?	YES	NO	Are there public areas inside the settlement for the social interaction of people?	YES	NO

5. HEALTH

How is the health of your family?	VERY GOOD	GOOD	POOR	Approximately how much are you spending in medical treatment yearly?	R ___

Has your family experienced any respiratory illnesses such as TB, Asthma in the past year?	YES	NO	Has your family experienced waterborne diseases such as diahorrea in the past year?	YES	NO

6. FOOD GARDEN

Approximately how much is spent in food monthly?	R ___	Do you have a food garden?	YES	NO	Are there existing fruit trees?	YES	NO

If you don't have a food garden, would you be interested in establishing one to provide food for your family?	YES	NO	Would you be available to share community food gardens with your neighbours?	YES	NO

7. WASTE

How much waste is generated weekly?	1 BLACK BAG	2 BLACK BAGS	3 OR MORE BLACK BAGS	Would you be available to separate your waste products and bring them to community waste collection points ?	YES	NO

Do you avoid placing some materials in your black bag for reusing them later?	YES	NO

8. TRANSPORT

Does anyone own?	A CAR	A BICYCLE	OTHER	What public transport is used ?	TAXIS	BUSES	TRAIN	OTHER

How much of household income is spent on transport monthly?	R 150

9. COMFORT AND QUALITY OF LIFE

Is your house temperature in WINTER?	ACCEPTABLE	COLD	VERY COLD	Is your house temperature in SUMMER?	ACCEPTABLE	HOT	VERY HOT

Do you need to use lights in your house during the day?	YES	NO

Are there shade trees that provide shadow in summer?	YES	NO

How many hours does your family spend at home a day?		When does your family usually stay at home?	MORNING	AFTERNOON	EVENING	NIGHT

Are you satisfied with your house?	YES	NO	if not, describe the main negative aspects:	leaks from roof

THANK YOU

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

1. HOUSEHOLD DEMOGRAPHIC DATA AND HOUSING TYPE

House N°:	253	N° of adults:	1	N° of children :	2
Number of years lived here:	4	Are you the owner or a renter?		OWNER	RENTER
How many rooms do you have?	1	Do you have dedicated sleeping space?		YES	NO
Are there existing formal extensions?	YES	NO	Are there existing informal extensions/outhouses?	YES	NO
		Are you planning to extend your house?		YES	NO

What did you live in before moving here?	ROOM	BRICK HOUSE	BACKYARD	INFORMAL SETTLEMENT	CAR	CARAVAN	TENT

Why did you decide to live here?	WANTED A PLACE OF MY OWN	NEEDED MORE SPACE	EXPERIENCED CONFLICT WITH PEOPLE LIVING WITH ME	COULD NOT AFFORD RENT	EVICTED BY LANDLORD	WANTED TO BE CLOSER TO WORK

2. ENERGY (HEATING, COOLING, COOKING, WATER HEATING, LIGHTING)

Approximately how much do you pay for electricity monthly?	R 30	What kind of electricity meter do you have?	PREPAID / ACCOUNT

Where do you get electricity from?	OWN ELECTRICITY BOX	ELECTRICITY POLES	NEIGHBOURS

NO

What energy sources do you use for space heating?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY
What energy sources do you use for preparing meals?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY

What cooking, heating and cooling appliances are being used in the house?	2 PLATE STOVE	MICROWAVE	HEATER	KETTLE	FAN	FRIDGE	OVEN

Do you use a wonderbag for preparing meals?	YES / NO			
Do you use a heater to keep warm in winter?	YES / NO	Is there a ceiling?	YES	NO
Do you use a fan to cool your house in summer?	YES / NO			

How do you heat up water for washing (personal, laundry, dishes)?	GEYSER	KETTLE	PLOT ON STOVE	OTHER

How many times a day do you heat up water with a kettle/on stove?		How many litres do you heat up each time?	
How many light fittings are being used in main house?	N° OF STANDARD INCANDESCENT:	1	N° OF COMPACT FLUORESCENT:
Would the owner /resident be interested in a building user's guide that teaches how to save energy in your house?	YES	NO	

3. WATER, PLUMBING FACILITIES AND RAINWATER

Approximately how much do you pay for water monthly?	R____	Is there a water meter?	YES / NO
Do you use the communal standpipe for any of your water needs?	YES / NO		
Is there any property leaks?	YES / NO		

How do you get water?	INDOOR TAP	OUTDOOR TAP	COMMUNAL TAP	NEIGHBOUR

What bathroom facilities are there in your house?	TOILET	SHOWER	BATH	BASIN

What is happening to greywater after washing dishes or clothes??	HAVE A SINK CONNECTED TO THE SEWER	THROW IN ROAD, YARD OR NEARBY	POURED DOWN DRAIN IN SHOWER	USED IN FOOD GARDEN

Would you be interested in a rainwater tank for backup water supply and for a food garden?	YES	NO

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

4. EMPLOYMENT, PARTICIPATION AND SOCIAL INTERACTION

N° of people in household with:	FORMAL JOBS: N°		INFORMAL WORKS: N°		SMALL BUSINESSES: N°		GRANT INCOME N°	X

Approximate combined household	R____	Would you be interested in expressing your needs to the designers and the Municipality before they build your house?	~~YES~~	NO	Would you have been available to live in multi-unit residential buildings (i.e. maisonette/rowhouses)?	YES	~~NO~~

Would you be interested in being engaged in the construction of your house?	YES	NO	Would you be interested in learning green jobs (i.e. water harvesting installations)?	~~YES~~	NO	Are there public areas inside the settlement for the social interaction of people?	YES	~~NO~~

5. HEALTH

How is the health of your family?	VERY GOOD	~~GOOD~~	POOR	Approximately how much are you spending in medical treatment yearly?	R_____

Has your family experienced any respiratory illnesses such as TB, Asthma in the past year?	YES	NO	Has your family experienced waterborne diseases such as diahorrea in the past year?	YES	NO

6. FOOD GARDEN

Approximately how much is spent in food monthly?	R____	Do you have a food garden?	~~YES~~	NO	Are there existing fruit trees?	YES	~~NO~~

If you don't have a food garden, would you be interested in establishing one to provide food for your family?	YES	NO	Would you be available to share community food gardens with your neighbours?	~~YES~~	NO

7. WASTE

How much waste is generated weekly?	1 BLACK BAG	~~2 BLACK BAGS~~	3 OR MORE BLACK BAGS	Would you be available to separate your waste products and ~~bring them to community waste collection points~~?	~~YES~~	NO

Do you avoid placing some materials in your black bag for reusing them later?	YES	~~NO~~

8. TRANSPORT

Does anyone own?	A CAR	A BICYCLE	OTHER	What public transport is used ?	~~TAXIS~~	BUSES	TRAIN	OTHER

How much of household income is spent on transport monthly?	R 300

9. COMFORT AND QUALITY OF LIFE

Is your house temperature in WINTER?	ACCEPTABLE	COLD	~~VERY COLD~~	Is your house temperature in SUMMER?	ACCEPTABLE	HOT	~~VERY HOT~~

Do you need to use lights in your house during the day?	YES	~~NO~~

Are there shade trees that provide shadow in summer?	YES	~~NO~~

How many hours does your family spend at home a day?		When does your family usually stay at home?	MORNING	~~AFTERNOON~~	~~EVENING~~	NIGHT

Are you satisfied with your house?	~~YES~~	NO	if not, describe the main negative aspects:	_____

THANK YOU

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

1. HOUSEHOLD DEMOGRAPHIC DATA AND HOUSING TYPE

House N°: 379 BULWER 7	N° of adults: 3	N° of children : 3

Number of years lived here: 1	Are you the owner or a renter?	OWNER	RENTER
How many rooms do you have? 3	Do you have dedicated sleeping space?	YES	NO
Are there existing formal extensions?	YES / NO	Are there existing informal extensions/outhouses?	YES / NO
	Are you planning to extend your house?	YES	NO

What did you live in before moving here?	ROOM	BRICK HOUSE	BACKYARD	INFORMAL SETTLEMENT	CAR	CARAVAN	TENT

Why did you decide to live here?	WANTED A PLACE OF MY OWN	NEEDED MORE SPACE	EXPERIENCED CONFLICT WITH PEOPLE LIVING WITH ME	COULD NOT AFFORD RENT	EVICTED BY LANDLORD	WANTED TO BE CLOSER TO WORK

2. ENERGY (HEATING, COOLING, COOKING, WATER HEATING, LIGHTING)

Approximately how much do you pay for electricity monthly? R120	What kind of electricity meter do you have?	PREPAID	ACCOUNT

Where do you get electricity from?	OWN ELECTRICITY BOX	ELECTRICITY POLES	NEIGHBOURS

What energy sources do you use for space heating?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY
What energy sources do you use for preparing meals?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY

What cooking, heating and cooling appliances are being used in the house?	2 PLATE STOVE	MICROWAVE	HEATER	KETTLE	FAN	FRIDGE	OVEN

Do you use a wonderbag for preparing meals?	YES	NO
Do you use a heater to keep warm in winter?	YES	NO
Do you use a fan to cool your house in summer?	YES	NO

Is there a ceiling?	YES	NO

How do you heat up water for washing (personal, laundry, dishes)?	GEYSER	KETTLE	PLOT ON STOVE	OTHER

How many times a day do you heat up water with a kettle/on stove? 3	How many litres do you heat up each time?

How many light fittings are being used in main house?	N° OF STANDARD INCANDESCENT:	N° OF COMPACT FLUORESCENT: 3

Would the owner /resident be interested in a building user's guide that teaches how to save energy in your house?	YES	NO

3. WATER, PLUMBING FACILITIES AND RAINWATER

Approximately how much do you pay for water monthly? R free	Is there a water meter?	YES	NO

Do you use the communal standpipe for any of your water needs?	YES	NO

How do you get water?	INDOOR TAP	OUTDOOR TAP	COMMUNAL TAP	NEIGHBOUR

Is there any property leaks?	YES	NO

What bathroom facilities are there in your house?	TOILET	SHOWER	BATH	BASIN

What is happening to greywater after washing dishes or clothes??	HAVE A SINK CONNECTED TO THE SEWER	THROW IN ROAD, YARD OR NEARBY	POURED DOWN DRAIN IN SHOWER	USED IN FOOD GARDEN

Would you be interested in a rainwater tank for backup water supply and for a food garden?	YES	NO

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

4. EMPLOYMENT, PARTICIPATION AND SOCIAL INTERACTION

N° of people in household with:	FORMAL JOBS: N°		INFORMAL WORKS: N°		SMALL BUSINESSES: N°		GRANT INCOME N°	

Approximate combined household	R___

Would you be interested in expressing your needs to the designers and the Municipality before they build your house?	YES	NO

Would you have been available to live in multi-unit residential buildings (i.e. maisonette/rowhouses)?	YES	NO

Would you be interested in being engaged in the construction of your house?	YES	NO

Would you be interested in learning green jobs (i.e. water harvesting installations)?	YES	NO

Are there public areas inside the settlement for the social interaction of people?	YES	NO

5. HEALTH

How is the health of your family?	VERY GOOD	GOOD	POOR

Approximately how much are you spending in medical treatment yearly?	R___

Has your family experienced any respiratory illnesses such as TB, Asthma in the past year?	YES	NO

Has your family experienced waterborne diseases such as diahorrea in the past year?	YES	NO

6. FOOD GARDEN

Approximately how much is spent in food monthly?	R___

Do you have a food garden?	YES	NO

Are there existing fruit trees?	YES	NO

If you don't have a food garden, would you be interested in establishing one to provide food for your family?	YES	NO

Would you be available to share community food gardens with your neighbours?	YES	NO

7. WASTE

How much waste is generated weekly?	1 BLACK BAG	2 BLACK BAGS	3 OR MORE BLACK BAGS

Would you be available to separate your waste products and bring them to community waste collection points ?	YES	NO

Do you avoid placing some materials in your black bag for reusing them later?	YES	NO

8. TRANSPORT

Does anyone own?	A CAR	A BICYCLE	OTHER

What public transport is used ?	TAXIS	BUSES	TRAIN	OTHER

How much of household income is spent on transport monthly?	R___

9. COMFORT AND QUALITY OF LIFE

Is your house temperature in WINTER?	ACCEPTABLE	COLD	VERY COLD

Is your house temperature in SUMMER?	ACCEPTABLE	HOT	VERY HOT

Do you need to use lights in your house during the day?	YES	NO

Are there shade trees that provide shadow in summer?	YES	NO

How many hours does your family spend at home a day?	

When does your family usually stay at home?	MORNING	AFTERNOON	EVENING	NIGHT

Are you satisfied with your house?	YES	NO

if not, describe the main negative aspects:	_____ _____ _____ _____

THANK YOU

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

1. HOUSEHOLD DEMOGRAPHIC DATA AND HOUSING TYPE

House N°:		N° of adults:	3	N° of children :	3
Number of years lived here:	4	Are you the owner or a renter?	OWNER		RENTER
How many rooms do you have?	2	Do you have dedicated sleeping space?	YES		NO
Are there existing formal extensions?	YES	NO	Are there existing informal extensions/outhouses?	YES	NO
		Are you planning to extend your house?	YES		NO

What did you live in before moving here?	ROOM	BRICK HOUSE	BACKYARD	INFORMAL SETTLEMENT	CAR	CARAVAN	TENT
				X			

Why did you decide to live here?	WANTED A PLACE OF MY OWN	NEEDED MORE SPACE	EXPERIENCED CONFLICT WITH PEOPLE LIVING WITH ME	COULD NOT AFFORD RENT	EVICTED BY LANDLORD	WANTED TO BE CLOSER TO WORK
	X					

2. ENERGY (HEATING, COOLING, COOKING, WATER HEATING, LIGHTING)

Approximately how much do you pay for electricity monthly?	R No electricity	What kind of electricity meter do you have?	PREPAID	ACCOUNT

Where do you get electricity from?	OWN ELECTRICITY BOX	ELECTRICITY POLES	NEIGHBOURS
		X	

What energy sources do you use for space heating?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY
	X				

What energy sources do you use for preparing meals?	WOOD	COAL	GAS	PARAFFIN	ELECTRICITY
	X				

What cooking, heating and cooling appliances are being used in the house?	2 PLATE STOVE	MICROWAVE	HEATER	KETTLE	FAN	FRIDGE	OVEN
	X	X		X		X	X

Do you use a wonderbag for preparing meals?	YES	NO			
Do you use a heater to keep warm in winter?	YES	NO	Is there a ceiling?	YES	NO
Do you use a fan to cool your house in summer?	YES	NO			

How do you heat up water for washing (personal, laundry, dishes)?	GEYSER	KETTLE	PLOT ON STOVE	OTHER
			X	

How many times a day do you heat up water with a kettle/on stove?		How many litres do you heat up each time?	

How many light fittings are being used in main house?	N° OF STANDARD INCANDESCENT:	4 complete	N° OF COMPACT FLUORESCENT:	

Would the owner /resident be interested in a building user's guide that teaches how to save energy in your house?	YES	NO
	X	

3. WATER, PLUMBING FACILITIES AND RAINWATER

Approximately how much do you pay for water monthly?	R None	Is there a water meter?	YES / NO

Do you use the communal standpipe for any of your water needs?	YES	NO	How do you get water?	INDOOR TAP	OUTDOOR TAP	COMMUNAL TAP	NEIGHBOUR
					X		

Is there any property leaks?	YES	NO
		X

What bathroom facilities are there in your house?	TOILET	SHOWER	BATH	BASIN
	X			

What is happening to greywater after washing dishes or clothes??	HAVE A SINK CONNECTED TO THE SEWER	THROW IN ROAD, YARD OR NEARBY	POURED DOWN DRAIN IN SHOWER	USED IN FOOD GARDEN
		X		

Would you be interested in a rainwater tank for backup water supply and for a food garden?	YES	NO
	X	

BULWER POST-OCCUPANCY SURVEY

(please check the right box or insert the number of items)

4. EMPLOYMENT, PARTICIPATION AND SOCIAL INTERACTION

N° of people in household with:	FORMAL JOBS: N° 1	INFORMAL WORKS: N°	SMALL BUSINESSES: N°	GRANT INCOME N°

Approximate combined household	R	Would you be interested in expressing your needs to the designers and the Municipality before they build your house?	~~YES~~	NO	Would you have been available to live in multi-unit residential buildings (i.e. maisonette/rowhouses)?	~~YES~~	NO
Would you be interested in being engaged in the construction of your house?	YES	NO	Would you be interested in learning green jobs (i.e. water harvesting installations)?	~~YES~~	NO	Are there public areas inside the settlement for the social interaction of people?	YES	~~NO~~

5. HEALTH

How is the health of your family?	VERY GOOD	~~GOOD~~	POOR	Approximately how much are you spending in medical treatment yearly?	R	
Has your family experienced any respiratory illnesses such as TB, Asthma in the past year?	YES	NO		Has your family experienced waterborne diseases such as diahorrea in the past year?	YES	NO

6. FOOD GARDEN

Approximately how much is spent in food monthly?	R	Do you have a food garden?	~~YES~~	NO	Are there existing fruit trees?	YES	~~NO~~
If you don't have a food garden, would you be interested in establishing one to provide food for your family?		~~YES~~	NO	Would you be available to share community food gardens with your neighbours?		~~YES~~	NO

7. WASTE

How much waste is generated weekly?	1 BLACK BAG	2 BLACK BAGS	3 OR MORE BLACK BAGS	Would you be available to separate your waste products and ~~bring them to community waste collection points~~ ?	~~YES~~	NO
Do you avoid placing some materials in your black bag for reusing them later?					YES	NO

8. TRANSPORT

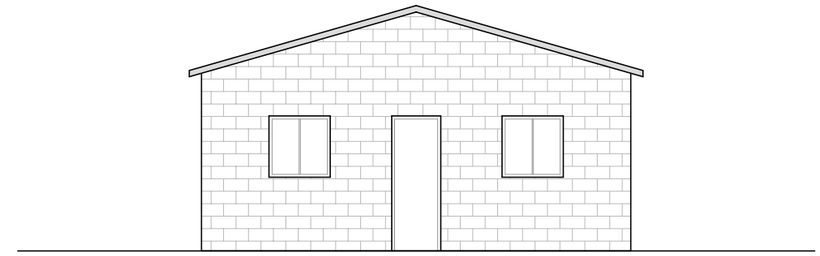
Does anyone own?	A CAR	A BICYCLE	OTHER	What public transport is used ?	~~TAXIS~~	BUSES	TRAIN	OTHER
How much of household income is spent on transport monthly?	R							

9. COMFORT AND QUALITY OF LIFE

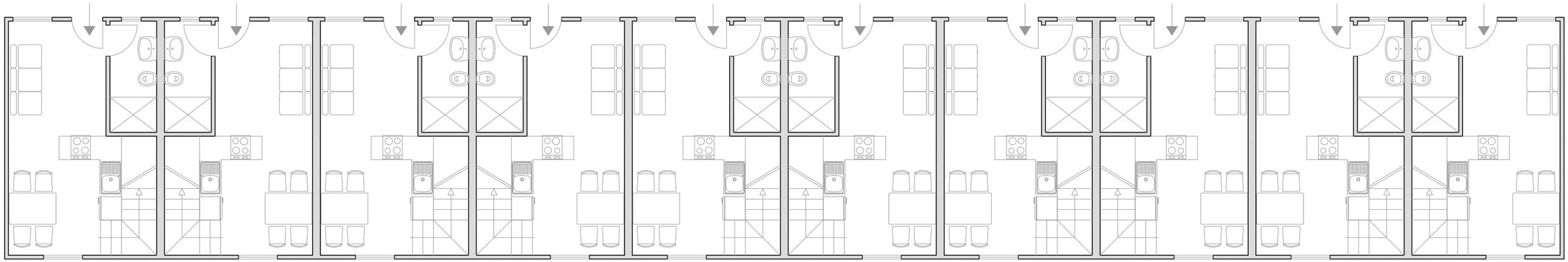
Is your house temperature in WINTER?	ACCEPTABLE	COLD	~~VERY COLD~~	Is your house temperature in SUMMER?	ACCEPTABLE	~~HOT~~	VERY HOT
Do you need to use lights in your house during the day?					YES	~~NO~~	
Are there shade trees that provide shadow in summer?					YES	~~NO~~	
How many hours does your family spend at home a day?		When does your family usually stay at home?	~~MORNING~~	~~AFTERNOON~~	~~EVENING~~	~~NIGHT~~	
Are you satisfied with your house?	YES	~~NO~~		if not, describe the main negative aspects:	looks from heavy realm		

THANK YOU

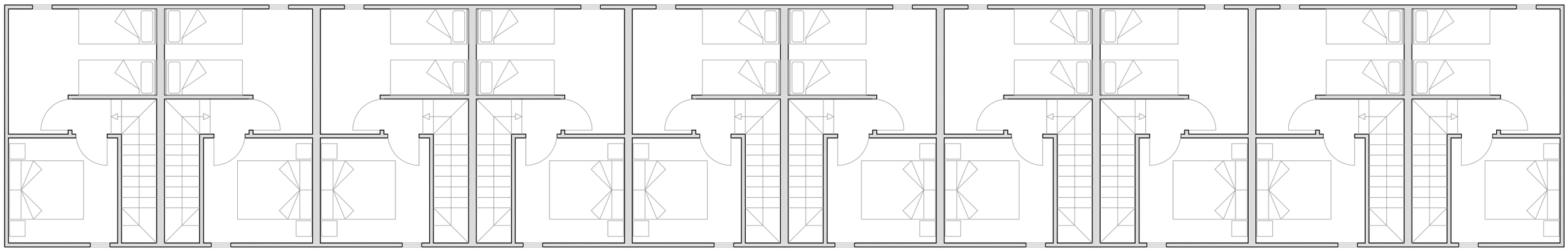
APPENDIX B: CAD DRAWINGS AND REPRESENTATIVE SKETCHES OF THE TRADITIONAL RDP DETACHED TYPOLOGY AND THE PROPOSED ALTERNATIVE BUILDING TYPOLOGIES



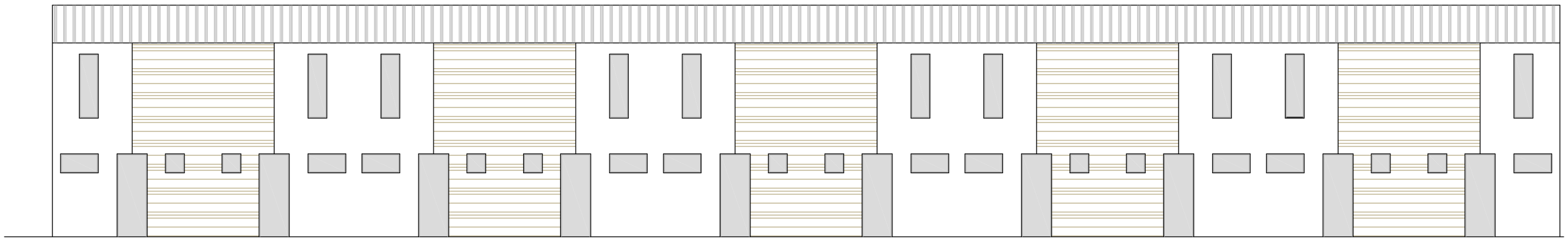
Plan and South elevation common practice
Scale 1:100



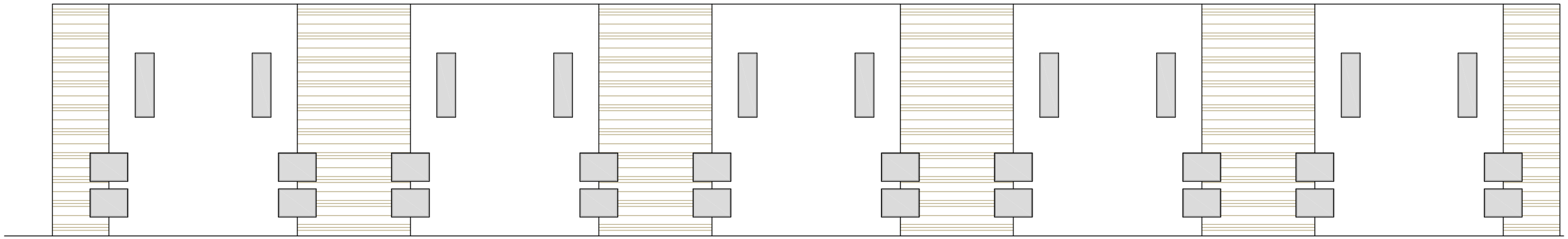
Ground Floor Plan Row House Housing Typology
Scale 1:100



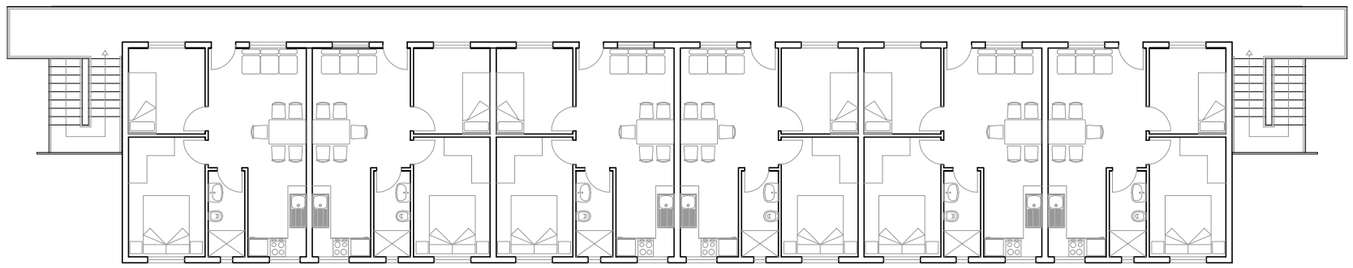
First Floor Plan Row House Housing Typology
Scale 1:100



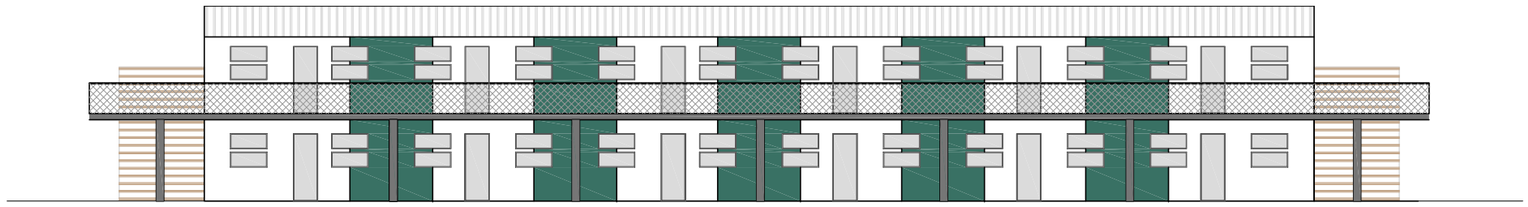
North Elevation Row House Housing Typology
Scale 1:100



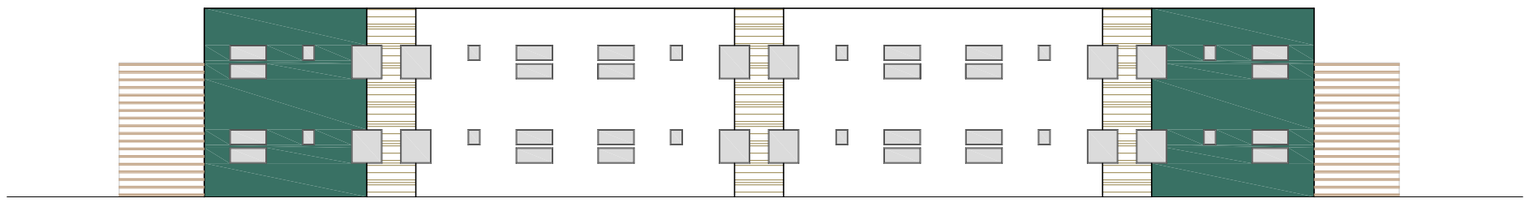
South Elevation Row House Housing Typology
Scale 1:100



First Floor Plan Maisonette #1 Housing Typology
Scale 1:200



North Elevation Maisonette #1 Housing Typology
Scale 1:200

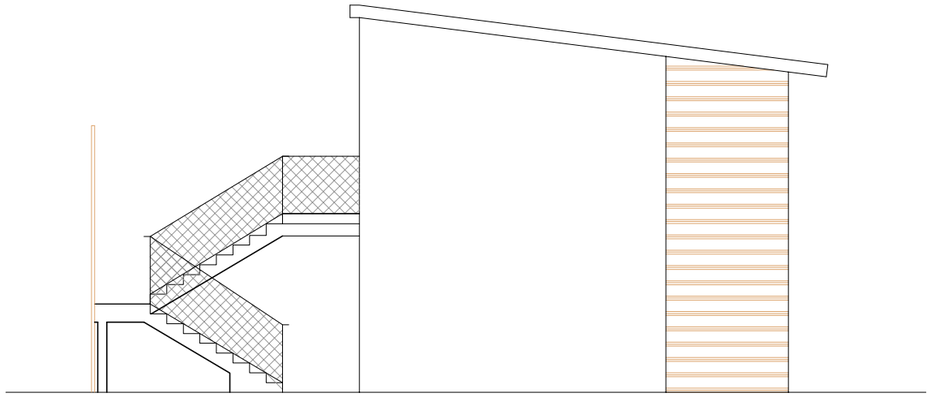


South Elevation Maisonette #1 Housing Typology
Scale 1:200

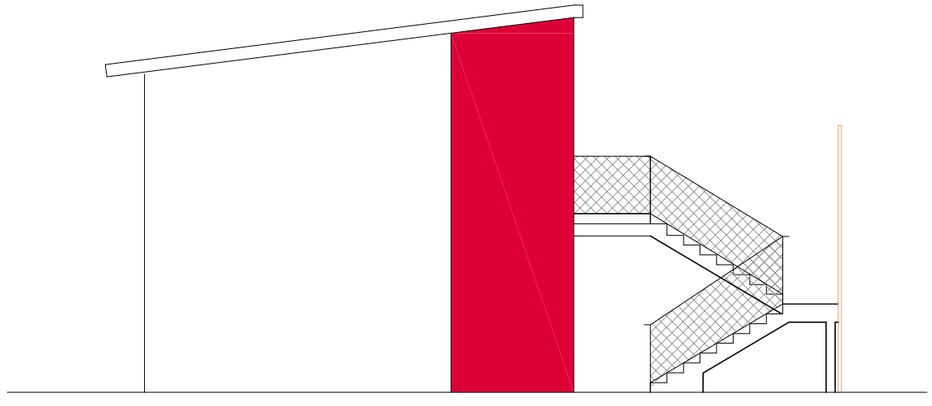
0 1 3 5 10 20 m

First Floor Plan Maisonette #2 Housing Typology
Scale 1:100

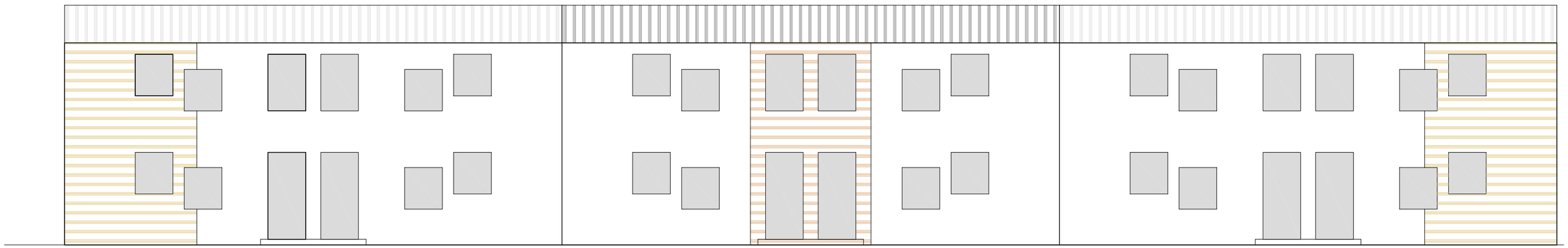
0 1 3 5 10 20 m



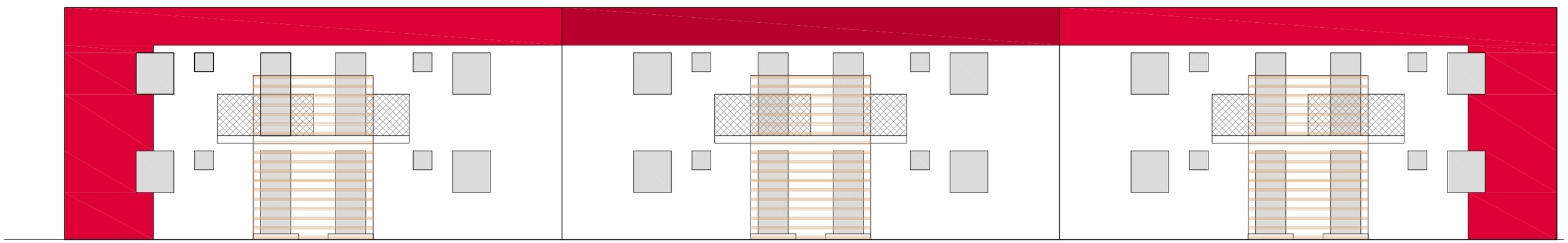
East Elevation Maisonette #2 Housing Typology
Scale 1:100



West Elevation Maisonette #2 Housing Typology
Scale 1:100



North Elevation Maisonette #2 Housing Typology
Scale 1:100

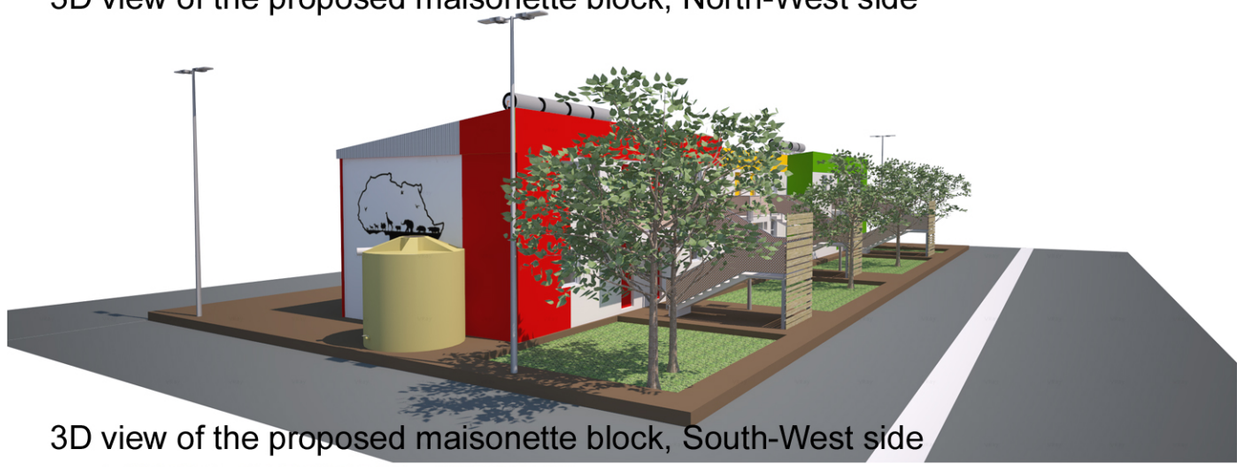


South Elevation Maisonette #2 Housing Typology
Scale 1:100

3D view of the proposed maisonette block, North facade

3D view of the proposed maisonette block, South-East side

3D view of the proposed maisonette block, North-West side



3D view of the proposed maisonette block, East facade

3D view of the proposed maisonette block, South-West side

3D view of the proposed maisonette block, North-East side

APPENDIX C: MAIN DATA USED FOR THE DYNAMIC BUILDING ENERGY AND COMFORT PERFORMANCE ANALYSIS

Software:

Simulation Package: EnergyPlus, developed by the Department of Energy in the Lawrence Berkeley National Laboratory in the USA.

Graphic User Interface: DesignBuilder software package. DesignBuilder is a state-of-the-art software tool for checking building energy, carbon, lighting and comfort performance and a comprehensive user interface to EnergyPlus dynamic thermal simulation engine. It includes a £D modeller and allows all materials parameters to interface with EnergyPlus.

Weather data:

The weather data file of the climatic zone 1 (SANS 204) of Johannesburg, officially released by South African Agreement, was used as a valuable reference for the energetic prediction, as motivated in the sub-chapters 3.3, 4.4.3 and 4.5.

Air exchange rate:

The infiltration rate was set to 0,8 air changes per hour (ac/h), assuming a poor quality of construction.

Internal loads:

Lighting load was set to 2 W/m^2 assuming compact fluorescent bulbs.

Occupancy was assumed to be 5 people per unit.

Appliances and plug loads were set to 5 W/m^2, apart from the kitchen zone, in which the cooking loads were set to 45 W/m^2.

Construction and materials details:

Roof: the government specification was used as base case: profiled metal on purlin rafters.

Ground floor: concrete surface bed.

Walls: 140 mm concrete block (thermal conductivity 0,620 W/m K, specific heat 840 J/kg J, density 1040 kg/m^3) wall plastered as base case.

Windows: 3 mm single glass panes with aluminium frame.

Doors: standard solid timber doors.

Proposed green additional construction strategies scenario:

Ceiling: a thermal insulating ceiling made of 40 mm extruded polystyrene board (thermal conductivity 0,035 W/m K, specific heat 1400 J/kg J, density 25 kg/m^3) was used in the upper units of the maisonette building.

Walls: a 106 mm + 106 mm double leaf clay brick (thermal conductivity 0,620 W/m K, specific heat 800 J/kg J, density 1900 kg/m^3) wall plastered was used for the maisonette units. (The cavity wall option was not considered because it is hard to preserve the thermal insulating performance of the air gap in the condition of poor quality of construction of this kind of houses. The generation of convective currents of air within the cavity in fact risks to invalidate its thermal insulation potential. The double leaf brick/block wall was not considered due to affordability criteria and cost constraints.)

Heating system:

Resistance heating with Coefficient of Performance of 1 and a setpoint temperature of 20°C (Due to the affordability criteria and cost constraints, more advanced and higher performance systems were not considered).

Schedules:

A residential template provided by the software was used, customised to the assessed target group. The resulting schedules were based on a seven-day operation. Each zone had a different schedule applied to it for lighting, appliances use, occupancy, heating and in case of the kitchen cooking.

APPENDIX D: PRELIMINARY COST ASSESSMENT OF THE COMMON RDP HOUSING PRACTICE AND THE PROPOSED GREEN SCENARIO

Preliminary Cost Assesment Detached house	Description	Quantity	Unit	Unit Rate	Total Cost Rands
A0	***TOP STRUCTURE 40 m²***				
	A0 PRELIMINARY AND GENERAL				
	TOTAL (Rands)				**6.003,02**
	A1 FOUNDATIONS				
	TOTAL (Rands)				**6.376,00**
	A2 GROUND FLOOR CONSTRUCTION				
	TOTAL (Rands)				**4.641,00**
	A3 ROOF				
	TOTAL (Rands)				**8.695,69**
	A4 EXTERNAL WALLING				
	TOTAL (Rands)				**19.750,50**
	A5 INTERNAL DIVISION				
	TOTAL (Rands)				**1.638,00**
	A6 FLOOR FINISHES				
	TOTAL (Rands)				**2.145,00**
	A7 INTERNAL WALL FINISHING				
	TOTAL (Rands)				**6.175,00**
	A8 ELECTRICAL INSTALLATION				
	TOTAL (Rands)				**3.659,00**
	A10 PLUMBING INSTALLTION				
	TOTAL (Rands)				**4.800,00**
	A11 PROVISIONAL SUMS				
	TOTAL (Rands)				**2.150,00**
					60.030,19
	TOTAL COST PER UNIT (RANDS)				**66.033,21**
B	***EXTERNAL WORKS (SETTLEMENT)***				
	COST PER UNIT (RANDS)				**30.693,45**
	TOTAL TOP STRUCTURE + EXT. WORKS (RANDS) PER UNIT				**96.726,66**

Preliminary Cost Assesment
Detached house

	Description	Quantity	Unit	Unit Rate	Total Cost Rands
A0	***TOP STRUCTURE 40 m²***				
A0	PRELIMINARY AND GENERAL				
1	Allowance for preliminary & general	0,1	item	60.030,19	6.003,02
	TOTAL (Rands)				**6.003,02**
A1	FOUNDATIONS				
1	Foundations comprising of RC 700 x 200mm strip footings incl excav min 600mm below top of s.b., incl. DPM, ROC & backfill and reinforcement (100kg/m3)	32	m	176,00	5.632,00
2	Ditto, but 600 x 185mm to 90mm walls	6	m	124,00	744,00
	TOTAL (Rands)				**6.376,00**
A2	GROUND FLOOR CONSTRUCTION				
1	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	39	m²	119,00	4.641,00
	TOTAL (Rands)				**4.641,00**
A3	ROOF				
1	New Corrugated profiled roof on PAR rafters/purlins incl. wall plates, straps, flashings, fixings, copings etc. as per manufacturers specs	41	m²	212,09	8.695,69
	TOTAL (Rands)				**8.695,69**
A4	EXTERNAL WALLING				
1	140mm concrete blockwork to external walls	66	m²	157,00	10.362,00
2	Bagging to new concrete blocks	66	m²	30,00	1.980,00
3	1 Undercoat & 1 ct paint to new brickwork	66	m²	35,00	2.310,00
4	External & internal timber doors incl. hinges, locks, frames and painting		item		2.185,00
5	Timber windows incl glazing & painting		item		2.450,00
6	Builders work to build in doors & windows	0,1		4.635,00	463,50
	TOTAL (Rands)				**19.750,50**
A5	INTERNAL DIVISION				
1	90mm half brick walls	14	m²	117,00	1.638,00
	TOTAL (Rands)				**1.638,00**
A6	FLOOR FINISHES				
1	25mm Screeds to floors	39	m²	55,00	2.145,00
	TOTAL (Rands)				**2.145,00**
A7	INTERNAL WALL FINISHING				
1	Bagging to new brick/block work	95	m²	30,00	2.850,00

	1	Ct undercoat & 1ct paint to new			
	2	walls	95 m²	35,00	3.325,00
		TOTAL (Rands)			**6.175,00**
A8		ELECTRICAL INSTALLATION			
	1	Allowance for new electrical DB board	item		494,00
	2	fittings	item		958,00
	3	Plug points	item		1.041,00
	4	Labour to electrical connections	item		1.166,00
		TOTAL (Rands)			**3.659,00**
A10		PLUMBING INSTALLTION			
	1	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	4	1.200,00	
		TOTAL (Rands)			**4.800,00**
A11		PROVISIONAL SUMS			
	1	WC	1	300,00	300,00
	2	Basins	1	300,00	300,00
	3	Bath	1	800,00	800,00
	4	Sinks	1	600,00	600,00
	5	Contractors mark-up	0,075	2.000,00	150,00
		TOTAL (Rands)			**2.150,00**
					60.030,19
		TOTAL COST PER UNIT (RANDS)			**66.033,21**
B		***EXTERNAL WORKS (SETTLEMENT)***			
	1	ROADS	15829	250,00	3.957.250,00
	2	KERB	5056	100,00	505.600,00
	3	SEWRE RETICULATION	5056	250,00	1.264.000,00
	4	WATER RETICULATION	5056	150,00	758.400,00
	5	STORM WATER	5056	200,00	1.011.200,00
	6	ELECTRICAL	5056	200,00	1.011.200,00
	7	STREET LIGHTING	535	3.000,00	1.605.000,00
		COST PER UNIT (RANDS)			**30.693,45**
		TOTAL TOP STRUCTURE + EXT. WORKS (RANDS) PER UNIT			**96.726,66**

Preliminary Cost Assesment
Maisonette block

A0	***TOP STRUCTURE***	
	A0 PRELIMINARY AND GENERAL	
	TOTAL (RANDS)	**61.323,54**
	A1 FOUNDATIONS	
	TOTAL (RANDS)	**23.278,80**
	A2 GROUND FLOOR CONSTRUCTION	
	TOTAL (RANDS)	**100.182,00**
	A4 ROOF	
	TOTAL (RANDS)	**60.021,47**
	A5 EXTERNAL WALLING	
	TOTAL (RANDS)	**202.078,80**
	A6 INTERNAL DIVISION	
	TOTAL (RANDS)	**57.217,68**
	A7 FLOOR FINISHES	
	TOTAL (RANDS)	**60.060,00**
	A8 INTERNAL WALL FINISHING	
	TOTAL (RANDS)	**88.800,40**
	A9 CEILINGS	
	TOTAL (RANDS)	**27.300,00**
	A10 ELECTRICAL INSTALLATION	
	TOTAL (RANDS)	**43.908,00**
	A11 PLUMBING INSTALLTION	
	TOTAL (RANDS)	**57.600,00**
	A12 PROVISIONAL SUMS	
	TOTAL (RANDS)	**25.800,00**
	A13 STAIRCASE	
	TOTAL (RANDS)	**71.400,00**
	TOTAL COST OF THE BLOCK (RANDS)	817.647,15
	TOTAL COST PER UNIT (RANDS)	**73.247,56**
B	***EXTERNAL WORKS***	
	TOTAL COST PER SETTLEMENT (RANDS)	4.663.150,00
	TOTAL COST PER UNIT (RANDS)	**14.945,99**
C	***GREEN IMPLEMENTATIONS***	
	TOTAL COST PER SETTLEMENT (RANDS)	3.574.000,00
	TOTAL COST PER UNIT (RANDS)	**11.455,13**
	TOTAL TOP STRUCTURE + EXT. WORKS + GREEN IMPLEMENTATION PER UNIT (RAN	**99.648,68**

Preliminary Cost Assesment
Maisonette block

	Description	Quantity	Unit	Unit Rate	Total Cost Rands
A0	***TOP STRUCTURE***				
A0	PRELIMINARY AND GENERAL				
1	Allowance for preliminary & general	0,08	Item	817.647,15	61.323,54
	TOTAL (RANDS)				**61.323,54**
A1	FOUNDATIONS				
1	Excavate in earth 2m deep for trenches				
2	25 MPa concrete in strip footing	98,80	m³	176,00	17.388,80
3	One block wall in foundations	47,50	m²	124,00	5.890,00
	TOTAL (RANDS)				**23.278,80**
A2	GROUND FLOOR CONSTRUCTION				
1	80mm Reinforced concrete surface bed incl. damp proof course, etc. and reinforcement (100kg/m3)	283,00	m²	119,00	33.677,00
2	Beam and block slab components	283,00	m²	235,00	66.505,00
	TOTAL (RANDS)				**100.182,00**
A4	ROOF				
1	Roof Constr. + Chromadek metal covering, Waterproofing + Insulation	283,00	m²	212,09	60.021,47
	TOTAL (RANDS)				**60.021,47**
A5	EXTERNAL WALLING				
1	230mm brickwork from 222 x 106 x 73mm core hole clay bricks to external walls	388,08	m²	300,00	116.424,00
2	Bagging to new concrete blocks	388,08	m²	30,00	11.642,40
3	1 Undercoat and 1 Ct paint to new brickwork	388,08	m²	30,00	11.642,40
4	External & internal timber doors incl. hinges, locks, frames and painting	36,00	number	500,00	18.000,00
5	Timber windows incl glazing & painting	51,60	m²	750,00	38.700,00
6	Builders work to build in doors & windows	0,10		56.700,00	5.670,00
	TOTAL (RANDS)				**202.078,80**
A6	INTERNAL DIVISION				
1	90mm half brick walls	325,84	m²	117,00	38.123,28
		163,20	m²	117,00	19.094,40
	TOTAL (RANDS)				**57.217,68**
A7	FLOOR FINISHES				
1	25mm Screeds to floors	546,00	m²	55,00	30.030,00

	TOTAL (RANDS)					**60.060,00**
A8	INTERNAL WALL FINISHING					
	1	Bagging to new brick/block work	1.366,16	m²	30,00	40.984,80
	2	1 Ct undercoat & 1ct paint to new walls	1.366,16	m²	35,00	47.815,60
	TOTAL (RANDS)					**88.800,40**
A9	CEILINGS					
	1	ceilling-extruded polystyrene insulation board 40mm	273,00		100,00	27.300,00
	TOTAL (RANDS)					**27.300,00**
A10	ELECTRICAL INSTALLATION					
	1	Allowance for new electrical DB board	12,00	item	494,00	5.928,00
	2	Light points, switches and fittings	12,00	item	958,00	11.496,00
	3	Plug points	12,00	item	1.041,00	12.492,00
	4	Labour to electrical connections	12,00	item	1.166,00	13.992,00
	TOTAL (RANDS)					**43.908,00**
A11	PLUMBING INSTALLTION					
	1	All plumbing including taking possession of, fitting and connecting fittings incl dishwasher and washing machine points and connecting to supply and waste points	48,00	item	1.200,00	
	TOTAL (RANDS)					**57.600,00**
A12	PROVISIONAL SUMS					
	1	WC	12,00	number	300,00	3.600,00
	2	Basins	12,00	number	300,00	3.600,00
	3	Bath	12,00	number	800,00	9.600,00
	4	Sinks	12,00	number	600,00	7.200,00
	5	Contractors mark-up	0,08	number	24.000,00	1.800,00
	TOTAL (RANDS)					**25.800,00**
A13	STAIRCASE					
	1	Concrete staircase including cantilevering slabs and parapets	3,00	item	23.800,00	71.400,00
	TOTAL (RANDS)					**71.400,00**
	TOTAL COST OF THE BLOCK (RANDS)					817.647,15
	TOTAL COST PER UNIT (RANDS)					**73.247,56**
B	***EXTERNAL WORKS***					
	1	ROADS	7.855,00	m²	250,00	1.963.750,00
	2	PAVEMENT	1.432,00	m²	150,00	214.800,00
	3	KERB	2.294,00	m²	100,00	229.400,00
	4	SEWRE	2.294,00	m²	250,00	573.500,00
	5	WATER	2.294,00	m²	150,00	344.100,00
	6	STORM WATER RETICULATION	2.294,00	m²	200,00	458.800,00
	7	ELECTRICAL	2.294,00	m²	200,00	458.800,00
	8	STREET LIGHTING	140,00	m²	3.000,00	420.000,00
	TOTAL COST PER SETTLEMENT (RANDS)					4.663.150,00
	TOTAL COST PER UNIT (RANDS)					**14.945,99**
C	***GREEN IMPLEMENTATIONS***					
	LANDSCAPING		10.000,00	m²	100,00	1.000.000,00
	SOLAR WATER HEATING SYSTEM (1 per unit x 312 units)		312,00	number	8.000,00	2.496.000,00
	RAINWATER TANK (2 per block x 26 blocks)		52,00	number	1.500,00	78.000,00
	TOTAL COST PER SETTLEMENT (RANDS)					3.574.000,00
	TOTAL COST PER UNIT (RANDS)					**11.455,13**
	TOTAL TOP STRUCTURE + EXT. WORKS + GREEN IMPLEMENTATION PER UNIT (RAND					**99.648,68**