Green architectural design for sustainable low-income housing in developing countries. A South African case study

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ABSTRACT

In developing countries, the residential sector is expected to have a high growth potential for energy consumption and especially for electricity usage, due to the currently large numbers of unelectrified households, the increased levels of urbanisation and related demand for electricity provision along with formal housing development.

In South Africa, about 19% of the households were living in 2010 in formal state-subsidised low-income houses, whereas 13% were living in informal dwellings. Also, the information on the delivery of formal residential units in major municipalities in 2007 showed that low-income housing accounted for about 36% of the number of units being delivered.

The sustainable development of low-income housing sector is therefore one of the main challenges for a developing country undertaking the advance of local green economy as South Africa, especially considering the quality of life of inhabitants and the complex socio-economic implications.

The rationale of this study is to investigate how strategic low-cost green measures, implemented in the planning of the settlement and in the architectural design of the buildings, can reduce resource consumption and improve the quality of life of low-income households toward sustainable communities. Using a case study in the South African context and through the assessment of design alternatives based on the settlement’s layout, building typology, passive strategies and related energy effects, this paper is aimed at demonstrating how green architectural design can play a crucial role to drive low-income housing sector toward sustainable living targets.

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

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 issues.

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 un-electrified households and the increased levels of urbanisation (Davis, 2011). In South Africa, the electricity demand of the residential sector accounts for about 18% of total electricity consumption and represents about 70% of the total housing energy consumption (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).

Moreover, 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 stock in the country. The environment usually 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. The complex
social issues related to the living conditions of low-income communities need to be addressed with an
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 resource consumption. The affordability of
the green measures to be implemented in current practice is also of key importance to allow an
effective transition to sustainable low-income settlements also in terms of economic convenience.

With these premises, the rationale of this study is to investigate how strategic low-cost green
design principles, implemented in the planning of the settlement and in the architectural design of the
buildings, can potentially address environmental targets, social issues and improve the quality of life
of people toward sustainable communities. The paper analyses a representative case study of a low-
income housing development in the town of Bulwer (Ingwe Municipality, KwaZulu-Natal Province),
conducting multitask assessments that evaluated design alternatives based on densification strategy,
building typology, green design strategies, using sustainable indicators as environmental and energy
impacts, social implications, cost effectiveness and safety. A participative process was developed as
integral part of the research as well as foundation of the design phase, through the results of a field
audit and interviews conducted on the inhabitants of the existing low-income settlement in Bulwer.

2. SUSTAINABLE TARGETS FOR SOUTH AFRICAN LOW-INCOME HOUSING

In 2010 about 19% of South African households were living in state-subsidised low-income houses,
whereas 13% in informal units (GHS, 2010). Between 2011 and 2014 the Government of South Africa
have planned to build 220,000 subsidised low-income houses per year (GCIS, 2011). The information
on the delivery of formal dwellings for the major municipalities in 2007 showed that low-income
housing accounted for about 36% of the number of units delivered (Milford, 2009).

In the last decades, many initiatives have been undertaken by the Government to improve living
conditions and provide shelter to low-income communities. In response to the large housing backlog,
the Government initiated a low-cost housing subsidised scheme (referred as RDP housing, from the
Reconstruction and Development Programme policy framework implemented in 1994 that aimed with
the White Paper on Housing to provide poor households access to adequate homes as well as basic
services on an equitable basis). Currently, a subsidy of Rand 64,666.00 (= about $ 6,550) is allocated
to subsidise the construction of the top structure of the RDP unit (DHS, 2013), traditionally based on a
detached one-storey house of about 40 m² in its plot including a separate toilet. Nevertheless, critics of
the RDP cited poor quality of houses and infrastructures, housing schemes often dreary in their layout
and not complying with building regulations (Lodge, 2003).

A comprehensive review of the programme led to the approval in 2004 of the Comprehensive
Plan for Sustainable Human Settlement, commonly referred to as “Breaking New Ground” (BNG),
that should have shifted the focus towards integrating communities and eradicating informal
settlements. 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). Nevertheless, low-cost housing
practice mostly continued to produce poor environmental quality and energy inefficient houses. Also
the National Housing Code of 2009 marked the lack of any environmental criteria in the common low-
income housing design practice and states that energy consumption patterns of low income households
have emerged as one of the most important factors influencing the national electricity demand (NHC,
2009). The new code incorporates some generic energy saving measures for RDP houses, but without
any specific quantitative prescriptions, risking consequently that the criteria are not implemented.

The new national regulation on energy efficiency in buildings, SANS 204 and SANS 10400-XA
of 2011, do not state clearly if the requirements for residential housing are mandatory also for low-
income housing, which instead would need to be addressed with a specific approach due to its critical socio-economic implications. 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 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 to low-quality, uncomfortable and “costly” houses.” (DEAT, 2005).

As observed by Castro-Lacouture et al. (2009), international best practices demonstrate 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 is observed (Milford, 2009) that in South Africa energy efficiency savings around 30% to 40% could be obtained in new buildings in the residential sector.

In the last years, several projects and research addressed the challenge of sustainable low-income settlements in the South Africa context. For example, Eicker (2008) described the 10x10 project in Freedom Park, a suburb of Cape Town, in which two-storey timber frame and sandbag infill row houses were designed and built with successful community involvement. Other projects failed in the planned objectives: for example in the RDP housing of Braamfischerville, located in Soweto (Johannesburg), six years later than the second development phase of the settlement, basic services as running water, sewerage and electricity were still absent (Moolla et al., 2011).

These examples 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.

Finally, the education and the participation of the inhabitants are integral parts of a sustainable design process. Recent research demonstrated that behavioural response has 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).

3. METHODOLOGY

The study is based on the synergistic interaction between three different research methods. A theoretical method focused on the available literature was used to define the background information about current design practice of low-income housing in South Africa and related policies in order to understand criticalities and main gaps to be addressed.

The second research method was a bottom-up approach based on the engagement of the local community. A post-occupancy questionnaire was created, organised with questions with multi-choice answers about environmental and socio-economic impact categories (energy, water, comfort, employment, transport, health, social aspects). Using the questionnaire, a field audit and interviews were personally conducted on a sample of thirty households in the existing RDP settlement in Bulwer. The aim was 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 the actual opinion and needs of inhabitants. The participative process is integral part of the methodology as well as foundation of the following research steps regarding the assessment of design alternatives.

The subsequent phase was the assessment of a local case study, regarding a potential development of RDP housing in the town of Bulwer. The case study approach was used to explore design alternatives through multitask assessments, based on sustainability indicators, that analysed various green strategies related to the layout of the settlement and the architectural features of the buildings. The strategies focused on densification criteria, building typology, passive design principles at the scale of the settlement and the building, low cost green implementations. The sustainability indicators used for the assessment of the green strategies were land use, people allocated, environmental and energy impacts, indoor comfort, social implications, safety and cost effectiveness.

Firstly, a study on the layout of the settlement was conducted to investigate the potential benefits of densification strategies and alternative building typologies compared with the common practice. This study comprises of two steps: a qualitative building typology assessment, whose results were
summarised in a matrix that compared through four grades of evaluation the common practice of the existing RDP settlement with two suitable variations for the new residential development (table 1). From the results, a scenario assessment of the most suitable option was developed to quantify the potential benefits. The quantitative assessment was conducted on a layout derived also from a preliminary qualitative energetic assessment of the settlement, which addressed environmental and energy efficient solutions for the community and the single building units from the early design stages.

Secondly, detailed quantitative energetic and comfort analyses through dynamic building energy simulations (software DesignBuilder/EnergyPlus) were conducted at the scale of the buildings, whose layout plan was designed following environmental criteria. The simulations evaluated the potential benefits of low-cost passive strategies compared with the common practice, in terms of heating energy consumption (kWh) and indoor comfort (Predicted Mean Vote). Finally, a cost assessment was done to compare the common practice with the proposed optimised scenario. The synergy between the three different research methods (theoretical, participative and case study) is oriented to an optimisation process of the design choices to meet sustainability targets with affordable and effective solutions.

4. THE LOW-INCOME HOUSING SETTLEMENT IN THE TOWN OF BULWER

Bulwer is located in the north-western portion of the Ingwe Municipality, in the Province of KwaZulu-Natal, close to the Drakensberg Mountains. The climate is classified as temperate interior (SANS 204), although the night winter temperatures in the coldest months drops below 0°C. 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. The typology is the traditional RDP one-storey detached house replicated without any consideration of green criteria, social interaction and facilities for inhabitants. In 2013 the Municipality commissioned a Urban Regeneration Plan to provide guidance towards the further development of land, including the revision for a residential development close to the RDP settlement. This study focused on the existing RDP settlement and proposed potential scenario development for the new residential area.

5. RESULTS AND DISCUSSION

This section discusses the outcomes of the various research steps. The results of the field audit and interviews conducted on the households of the existing RDP settlement are summarised as follows. About 40% of the houses did not have a separate sleeping place; 80% of the households would have needed more space but they could not afford a formal extension; 85% 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 an heater whereas the remaining people used wood or blankets to get warm in the coldest periods. All the families got water from a communal tap and heated it for personal use with kettles or on the stove; they did not reuse rainwater neither greywater. 55% of the households had a private food garden and 75% of the interviewed were interested to establish community vegetable gardens to provide secure food to the inhabitants. All the people complained the lack of communal areas for social interaction, 60% of them would have been available and interested in living in apartment buildings sharing facilities with neighbours. 93% of interviewed complained very cold indoor winter conditions and 50% also experienced very hot in the summer. Most families experienced problems with the quality of construction such as water leaks through the roof. The outcomes of the survey supported the decisional phase for proposing development scenarios for the new residential area. 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 could include different building typologies and related schemes of land use, community shared services that could realise cost saving considering the settlement as a whole. Firstly, a housing typologies study was conducted to evaluate potential alternative schemes to the traditional detached house. A qualitative cross comparison between the existing layout and two different schemes suitable
for the local context was done to investigate advantages and criticalities based on four impact categories. The outcomes are summarised in the matrix of typologies of table 1. The detached typology negatively affects most categories, especially in terms of environmental and safety aspects. The rowhouse and maisonette schemes are instead promoter of medium density, cost and energy saving and community interaction. The results of the matrix suggested a maisonette typology predominance development that could reach highest benefits for the aim of the study, considering especially the greater potential of social interaction and the economic saving due to maximum number of shared building components.

The subsequent analysis compared the existing low-density layout with medium-density scenarios (figure 1 and table 2), firstly studied in the same land as hypothetical scenario to investigate the densification potential, based on the combination of maisonette and rowhouse typologies, evaluating the increase of allocated households within the boundary of the existing settlement. The densification strategy was hence applied to the residential development area, based on the maisonette layout to minimise the land occupied, and demonstrated that the households allocated could be doubled compared with the existing settlement, but utilising half land area of the current RDP housing. The layout of the new settlement was based on environmental and climatic considerations for the local context, using preliminary qualitative energetic assessments (i.e. overshadowing analyses) 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. Communal vegetable gardens were considered as a crucial point for the development and a potential resource in terms of food cultivation and security, job creation, social integration and collaboration.

Each two-storey block of maisonettes comprised of 6 units of 47,50 m² 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, 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.

### Table 1. Matrix of typologies assessment (++ highly positive, + positive, – negative, –– highly negative)

<table>
<thead>
<tr>
<th>Economy</th>
<th>Typology 1 - Detached house (Common practice, 1 floor)</th>
<th>Typology 2 - Rowhouse (two-storey units, with private internal stair)</th>
<th>Typology 3 - Maisonette (two-storey building with one floor units, shared gallery each two upper floor units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>No cost for community areas (only private plots)</td>
<td>++ High cost saving for limited land utilisation, bulks and roads area</td>
<td>++ High cost saving for limited land utilisation, bulks and roads area</td>
</tr>
<tr>
<td></td>
<td>– Max number of building components per house</td>
<td>++ Most suitable to slope terrain</td>
<td>++ High cost saving due to maximum number of shared building components (walls, stairs)</td>
</tr>
<tr>
<td></td>
<td>-- Low cost-effective subsidy utilisation</td>
<td>+ Medium cost saving due to shared building walls</td>
<td>+ Suitable to slope terrain</td>
</tr>
<tr>
<td></td>
<td>-- Maximum land utilisation, bulks and roads areas</td>
<td>+ Efficient subsidy utilisation</td>
<td>+ Efficient subsidy utilisation</td>
</tr>
<tr>
<td></td>
<td>++ Maximum potential extension of the house</td>
<td>– Cost for public areas external works</td>
<td>– Cost for public areas external works</td>
</tr>
<tr>
<td>Social</td>
<td>++ Community areas for social interaction</td>
<td>– High cost for internal stair (one per unit)</td>
<td>– Cost for shared external stairs and balconies</td>
</tr>
<tr>
<td>implications</td>
<td>++ Potential of job creation in the community areas (i.e. vegetable gardens, gardening)</td>
<td>++ Community areas for social interaction</td>
<td>++ Community areas for social interaction</td>
</tr>
<tr>
<td>– Better sense of privacy</td>
<td>++ Limited potential extension of the house</td>
<td>++ Community areas for social interaction</td>
<td>++ Community areas for social interaction</td>
</tr>
<tr>
<td></td>
<td>– No community areas</td>
<td>= Diminished privacy</td>
<td>++ High level of social integration at building level</td>
</tr>
<tr>
<td></td>
<td>– Low social interaction</td>
<td>++ Potential of job creation in the community areas (i.e. vegetable gardens, gardening)</td>
<td>++ Potential of job creation in the community areas (i.e. vegetable gardens, gardening)</td>
</tr>
<tr>
<td>Energy</td>
<td>++ High surface area to volume ratio (S/V = 1.30/m)</td>
<td>+ Limited potential use of trees in public areas as shading devices (medium density typology)</td>
<td>++ Sense of communal/shared space</td>
</tr>
<tr>
<td>Environment</td>
<td>-- High potential shared shading systems</td>
<td>+ Medium potential use of trees in public areas as shading devices (medium density typology)</td>
<td>++ Low potential of job creation in the community areas (i.e. vegetable gardens, gardening)</td>
</tr>
<tr>
<td></td>
<td>-- High land utilisation</td>
<td>+ Low land utilisation</td>
<td>++ Potential of trees in public areas as shading devices (medium/high density typology)</td>
</tr>
<tr>
<td>Safety</td>
<td>++ Good visibility</td>
<td>++ Low surface area to volume ratio of the unit (S/V = 0.71/m)</td>
<td>++ Low surface area to volume ratio of the unit (S/V = 0.69/m)</td>
</tr>
<tr>
<td></td>
<td>+ Good visibility</td>
<td>++ Potential shading system using the external shared stairs and balcony (in hot climate)</td>
<td>++ Potential shading system using the external shared stairs and balcony (in hot climate)</td>
</tr>
<tr>
<td></td>
<td>++ Good visibility and security</td>
<td>++ High potential use of trees in public areas as shading devices (medium/high density typology)</td>
<td>++ High potential use of trees in public areas as shading devices (medium/high density typology)</td>
</tr>
<tr>
<td></td>
<td>++ Best surveillance and security</td>
<td>+= Low land utilisation</td>
<td>++ Low land utilisation</td>
</tr>
<tr>
<td></td>
<td>–– Poor visibility to the surroundings</td>
<td>++ Best surveillance and security</td>
<td>++ Shared balcony with the neighbours at the upper floor</td>
</tr>
<tr>
<td></td>
<td>–– Poor surveillance and security</td>
<td>++ Best visibility from the balcony</td>
<td>++ Shared balcony with the neighbours at the upper floor</td>
</tr>
</tbody>
</table>

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Figure 1. Layouts of the existing RDP settlement (left), hypothetical scenario (middle left), new development scenario (middle right), shadow range analysis of a proposed district (right)

Table 2. Density indicators for the existing settlement, hypothetical and development scenarios

<table>
<thead>
<tr>
<th></th>
<th>Existing settlement layout</th>
<th>Hypothetical scenario with densification strategy (same land)</th>
<th>Development scenario with densification strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land area occupied [ha]</td>
<td>12.7</td>
<td>12.7</td>
<td>5.4</td>
</tr>
<tr>
<td>Number of units</td>
<td>313</td>
<td>660</td>
<td>312</td>
</tr>
<tr>
<td>Unit gross area [m$^2$]</td>
<td>40</td>
<td>47.5</td>
<td>47.5</td>
</tr>
<tr>
<td>Gross density (n. of units/land area) [n. units/ha]</td>
<td>24.6</td>
<td>52</td>
<td>57.8</td>
</tr>
<tr>
<td>Roads area [ha]</td>
<td>1.6</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Population allocated (5 people per household) [n. people]</td>
<td>1565</td>
<td>3300</td>
<td>1560</td>
</tr>
<tr>
<td>Population density = n. people / land area [n. people /ha]</td>
<td>123.2</td>
<td>259.8</td>
<td>288.9</td>
</tr>
</tbody>
</table>

Figure 3. Layout plan of a block with maisonette units, south elevation and artist impression

Dynamic energy simulations were also conducted to evaluate the potential benefits of low cost passive design strategies to the energy consumption and indoor comfort, compared with the existing detached house scheme. RDP houses are in fact very inefficient not only due to the cost constraint, but also because they are built without any consideration of basic green design principles. For the analysis, assumptions had to be made due to the unavailability of comprehensive data for the weather stations close to Bulwer. The representative hourly weather data of the climatic zone 1 (Johannesburg) of South African energy efficiency regulation was therefore used as a valuable reference for the energetic prediction. Due to the cold climate of Bulwer, the results might be a bit conservative. The hourly operation of appliances, occupation, lighting and cooking was based on the operational schedules provided by the software, that were customised to the target group assessed and their habits, considering a seven day operation. The heating was supposed to be provided by an electrical heater (Coefficient of Performance = 1) operating to allow the spaces to be heated principally during their occupation. The infiltration rate was set to 0.8 ach/hour. The detached house was simulated with its traditional materials (concrete block walls, profiled metal roof on purlin rafters, aluminium frame with single glazing), the maisonette 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 40 mm of expanded polystyrene). 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 were considered with free running temperature with only internal and solar gains (which is
however a likely condition for low-income houses). Also in this regard, the results (figure 4) showed that the low surface area to volume ratio of the maisonettes and the green design choices adopted allow for a reduction of the heating energy consumption of about 550 kWh compared with the detached typology, confirmed also in terms of improved comfort (PMV values closer to the acceptable range). The two construction green implementations produced a further relevant reduction of heating consumption, especially in the upper floor unit in which the ceiling is highly effective (more than 50% of saving compared with the traditional construction assumption).

Finally a cost comparison assessment was conducted in order to evaluate the economic implications of the adopted densification strategy, that could 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 green measures for each unit (thermal insulating ceiling, improved thermal properties material for walls), additional green implementation for the buildings (i.e. rain water harvesting, solar heating) and for the settlement (vegetable gardens, communal areas). The proposed scenario could allow for a better quality of houses, including green features that could improve quality of life of people. 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, but would use more effectively the subsidy given by the government (R 64,666,00 (≈ $ 6.507,00) for top structure + R 22,000,00 (≈ $ 2.214,00) for municipal engineering services) to provide an improved quality of living, a better built and community environment for low-income communities.

Table 3. Cost comparison of the proposed maisonette unit with the traditional RDP detached house

<table>
<thead>
<tr>
<th></th>
<th>Top structure</th>
<th>External works</th>
<th>Additional green implementation</th>
<th>Total unit cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detached house</strong></td>
<td>Unit gross area 40 m²</td>
<td>Roads</td>
<td>Storm water reticulation</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Wall: 140 mm concrete blocks</td>
<td>Sewer reticulation</td>
<td>Electrical reticulation</td>
<td>(Detached house)</td>
</tr>
<tr>
<td></td>
<td>Internal partition only for the separate toilet</td>
<td>Water reticulation</td>
<td>Streets lighting</td>
<td>R 0.00 (≈ $ 0.00)</td>
</tr>
<tr>
<td><strong>Maisonette</strong></td>
<td>Unit gross floor area 47.50 m²</td>
<td>Roads</td>
<td>Storm water reticulation</td>
<td>Vegetable gardens</td>
</tr>
<tr>
<td></td>
<td>Wall: 230 mm clay bricks</td>
<td>Sewer reticulation</td>
<td>Electrical reticulation</td>
<td>1 Solar water heater per each unit</td>
</tr>
<tr>
<td></td>
<td>Internal partitions for toilette and two bedrooms</td>
<td>Kerbs</td>
<td>Streets lighting</td>
<td>Rainwater harvesting and rainwater tanks for each block</td>
</tr>
<tr>
<td></td>
<td>Thermal insulating ceilings (upper floor units)</td>
<td>Sewer reticulation</td>
<td>Streets lighting</td>
<td>(Maisonette)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water reticulation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. CONCLUSIONS

This paper aimed to explore how green architectural design can contribute to drive low-income housing sector toward sustainable living targets, combining environmental and social targets with economic effectiveness. Assessing the case study of a low-income settlement in the town of Bulwer...
(South Africa), the study experimented a participative approach to the design, whose strategies were firstly based on the needs expressed by the local community. Strategic low-cost green strategies at the scale of the settlement and the buildings were hence assessed in a scenario analysis of a potential low-cost housing development in Bulwer. The results demonstrated the potential benefits to households and whole community of multi-scale level green strategies that combined densification criteria, building typology assessment, passive design measures and social aims, showing that it is possible to provide higher standard of housing with affordable solutions. The outcomes of the study also suggest that the national subsidy could be redistributed favouring higher quality top structure of the houses, that could include some low cost green features, while limiting the amount for municipal engineering services whose cost could be reduced with densification strategies.

The use of dynamic energetic simulations allowed for quantifying the benefits of aggregate building typologies and strategic low-cost passive criteria in terms of energy saving and improved indoor comfort. Increasing the efficiency of the low-income housing sector could contribute to reduce the dependence from fossil and imported energy, hence enabling a more feasible transition to future energy self-efficient green infrastructures based on renewable sources.

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