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Comparisons, trade-offs and opportunities within the context of sustainability, contemporary vernacular architecture and innovation: A case study of Centani: Greenshops Financial Services Centre; and East London: University of Fort Hare, New Auditoria and Teaching Complex.

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1. INTRODUCTION:

Why is sustainability becoming more imperative? What are the common functional, ecological, ethical, social and design principles currently being used in South Africa? How could sustainability be incorporated into modern architectural and vernacular design within a regional context? Despite the popularity of using the terms “sustainability, innovation and vernacular architecture”, these remain ambiguous terms within the architectural profession.

Rather than construct synthetic, and generally insupportable, distinctions in some hypothetical sequence, one should rather choose to examine the sustainability, innovation and vernacular architecture within a specific region, chosen here is the eastern seaboard of the Eastern Cape. In so doing, identifying its source: people, traditions, cultures, materials and skills.

This paper will focus on three contemporary theoretical and practical terms within the architectural profession, these being sustainability; the introduction of innovative methods and materials; and vernacular architectural design within the South African Eastern Cape Province. Qualitative data will be employed by means of case studies whereby a comparative theoretical analysis may be performed between the Centani: Greenshops Financial Services Centre and the New Auditoria and Teaching Complex at the University of Fort Hare in East London. The aim is to critically analyse these case studies within the sustainable, vernacular and innovative contexts, thereby bridging the gap between the architectural academia and practice.

This paper aims to demonstrate the integrated bonds between the populate and community life, and their cultural and environmental content within both case studies. Within South Africa, there lies a traditional tapestry, a treasure of skills, craftsmanship and competence. The sensibility and the know-how to construct buildings within the Eastern Cape effectively with regard to the land, the climate and the resources at hand, all embody the values and needs that are specific to the region. In the case studies discussed, the buildings constructed – or that which is under construction – have often achieved in their integrity and authenticity, beauty of form and harmony of design.

2. Definitions and discussions:

2.1. Sustainability:

The report from the World Commission on Environment and Development (U.N., 1987) together with the writings of Conway (1985, p. 31-35), delineated sustainability as the ability to ensure that humanity meets the needs of the present, without compromising the ability of future generations to meet their own needs; and also the ability of a system to maintain productivity in spite of a major disturbance.

After much research regarding the meaning of sustainability, a concise but useful discussion of the foremost - though sometimes conflicting interpretations of what 'sustainability' is, and a brief explanation of premises of a human ecology perspective on vernacular architecture - both Lawrence (2006) and Hatfield Dodds (2000) suggest various basic principles that may be applied in professional practice to increase the sustainability of future buildings and settlements.

Using the architecture of the Eastern Cape Province as a focus to validate these principles, one should aim to meet, among others (Hatfield Dodds, 2000; Lawrence, 2006): the need to consider ecological and cultural diversity; the importance of interrelations between different geographical scales; the value of participatory approaches to development; the critical need to raise public awareness of the issues concerned; the provision of guarantees that economic activity does not over-exploit natural resources or exceed the capacity of the earth to adjust to the impacts of human activities on which sustenance is based; ensuring that ecological integrity and resilience to change is maintained by the amount and diversity of natural resources and other environmental assets; reducing inequalities between human societies and within specific human settlements by authorising institutions to be key actors in reconsidering the environmental and social consequences of the uses of natural resources by humans; maintaining human well-being and quality of life by promoting broader participation in decision-making, especially at the local community level; fostering ethical frameworks, moral values and attitudes that give more consideration to future generation and the non-human components of the world.

2.2. Vernacular Architecture:

According to Lawrence (2006, p. 110), vernacular buildings are human constructs that are the results of interrelations amid ecological, economic, material, political and social factors. Furthermore, Ozkan (2006, p. 108) further described vernacular architecture as the highest form of sustainable building, as it not only uses the most accessible materials, but also employs the widest available technologies.

Vernacular architecture comprises of the dwellings and other buildings of the people. Related to their environmental contexts and available resources, they are customarily owner- or community- built, utilizing a variety of traditional technologies. All forms of vernacular architecture are built to meet specific needs, accommodating the values, economies and ways of living of the cultures that produce them (AlSayyad, 2006; Asquith, 2006; Lawrence, 2006; Oliver, 1997; Ozkan, 2006).

Vernacular architecture among practicing architects, continues to be associated with the past, underdevelopment and poverty – often vernacular architecture in the Eastern Cape is viewed solely in the light of mud huts and thatch roofs. Despite the popular conceptions to the contrary, Asquith (2006, pp.1-2) noted vernacular building traditions not as remnants of an underdeveloped or romantic past, but rather as buildings of importance and relevance to many cultures and people in the world: past, present and future. Therefore, after the damnation of the general conception surrounding vernacular architecture as being the only harbinger of authenticity (or solely as African authenticity – lacking Western influence), as the container of a specific determined cultural meaning, as a static legacy of a past, what will emerge, also noted by AlSayyad (2006, p. xviii), is perhaps a twenty-first century South African vernacular which reflects the buildings of the people in a democratic country. The South African vernacular should therefore be viewed as a political project, a project whose principal mission is the dynamic interpretation and re-interpretation of its past in light of an ever-changing present.

2.3. Tradition:

Tradition can be defined as the creative processes through which people interpret past knowledge and experiences to face the challenges and demands of the present. The actual significance of tradition within architectural practice is often overlooked to allow for the prevailing Western influence, but as Bronner (2006, p. 5) notes, 'traditon should be seen as a reference to the learning that generates cultural expressions and the authority that precedent holds'.

This paper explicitly focuses on the way in which traditional cultures merge with contemporary innovation. Comparable to the proposal done by Vellinga (2006, p. 10), widening the Eastern Cape vernacular and traditional concepts - so that it includes all those buildings that are "distinctive cultural expressions of people who live in or feel attached to a particular place or locality" - would help the building traditions that are now called vernacular to exonerate themselves of the stigma of underdevelopment and a backward past, thereby enabling them as sources of architectural know-how, to assume an active part in the provision of sustainable architecture for the future.

2.4. Indigenous Knowledge and Innovation:

Why has the indigenous knowledge of the South African people – such an enormous and rich resource in our country – largely been ignored by our government and also the general public (Prain, 1992, p. 52)? Perhaps it is due to the lack of understading surrounding the terms 'tradition and vernacular', which as already noted, is far beyond the 'mud hut' and 'thatched roof' (Asquith, 2006, p.1-2).

The knowledge, experience and skills of the indigenous South African builders of the Eastern Cape still have an important contribution to make the creation of sustainable settlements and buildings needed in the future (Ozkan,2006, p. 108) as will be verified in the case study of Centani: Greenshops Financial Services Centre. Confirmed by Sawyer, (1992, p. vii) past and present indigenous knowledge does play a key role in sustainability. It seems imperative then, that an architectural perspective is created - in which valuable indigenous knowledge is integrated with equally valuable modern innovative knowledge (shown in the case study of the New Auditoria and Teaching Complex at the Fort Hare University), therefore enabling the development of settlements and buildings that are both contemporary and modern, yet which build upon the characteristics of the local vernacular traditions and therefore amalgamate within the cultural and ecological context.

Indigenous knowledge and innovation is, according to Hirji (2002, p. 313), ‘a system of methods, customs and traditions developed over many generations, through a traditional way of life of an in-depth knowledge of a system or systems by local people.

2.5. Apprenticeship:

The maintenance of an apprenticeship system, as was forged by Marchand (2006, p.51), in which one is bound to another to learn a trade that endows a community with not only technical skills but a sense of social identity and professional responsibility is the most effective way to guarantee a sustainable reproduction of a distinct architecture and an urban landscape imbued with changing and dynamic meaning for the Eastern Cape Xhosa-specific population that live in it. Architectural theory and practice, which encompasses all the factors that surround the art of building, is embedded within society and is passed on from one generation to the next by means of tradition and more often apprenticeship. It is when these cycles of transmission of information or technology are broken by outside forces that apprentice systems cease to be active (Ozkan, 2006, p. 108). Unfortunately, changes that ignore the complex nature of social and environmental forces, yield architecture which, since 1994 has been seen throughout the country in the Reconstruction and Development Programme (RDP).

Parallel to this, the changes since 1994 - when South Africa became a democracy - have been marked in recent years as individuals, families and whole communities have left the rural areas, and, often with no homes to go to, migrated to the cities, resulting in various informal settlements or squatter camps and other social problems, alongside political changes, resulting in militaristic ranks or low-cost RDP housing schemes rarely taking into account the culture in particular and seldom reflecting the values of the indigenous people.

In a country where the scarcity of energy resources and synthetic materials is only likely to increase, the determination to make use of abundant local resources, the reintroduction of an apprenticeship system along with the desire to respect and engage with the complexities of cultures, historical contexts, tradition and the pressing needs of habitat, will most certainly give rise to impressive, durable and socially conscious architecture.

3. Criteria for selecting specific case studies and their research systems:

Introduction to case studies

Selecting appropriate case examples has involved the weighing up of a number or factors: availability and accessibility of the relevant information; the appropriateness of examples to the validity of the research; on-site research as a key component to realizing the projects objectives in a proficient and equitable manner; the collection of analytical information; the evaluation of innovative methods and technologies; and the actual implementation thereof in the projects all play important roles (Voss, 1992).

The timeframe (2007-2012) has ensured that the case studies are recent, for the emphasis of the study. One has chosen not to use the familiar fiction, sometimes called the "ethnological present" which implies that the Eastern Cape society and its buildings subsist in an invariable, monotonous state, when in fact, the historical cultural methods of construction concerned have almost died out and most vernacular dwellings disappeared or demolished.

The case studies have been selected from a specific region, time period and architectural intension, so as to make relevant and unbiased comparisons. Region specifically, the Eastern Cape Province of South Africa was selected, further limiting the study to the coastline between East London and Port St. Johns. East London therefore being a primarily urban case study of the University of Fort Hare: New Auditoria and Teaching Complex due for completion in 2011. Centani (in the Old Transkei region north of East London) acts as a rural case study, with the introduction of the Greenshops Financial Services Centre which was completed in 2008.

Service specific as a public or community building, the East London University of Fort Hare with its New Auditoria and Teaching Complex serves student's needs in particular, with the Centani Greenshops Financial Service Centre acting a dual role as both a community hall and meeting place and also providing public financial services to the community. Both case studies have intentions which mirror their design language, with sustainability and innovation at the forefront thereof.

The Centani Greenshops Financial Service Centre was designed and managed by the architects Vernon Collis and Anna Cowen in association, from the Western Cape; while the New Auditoria and Teaching Complex at the University of Fort Hare in East London, was designed by local East London architects Ngonyama Okpanum Associates in association with Native Architecture.

3.1. Centani: Greenshops Financial Services Centre:

When cultural changes (national, political or governmental) occur, old buildings may be adapted to new ways of living, and new buildings may be altered in form to accommodate them (Oliver, 1987, p. 10). Similarly, the Greenshops Financial Services Centre, which was once a centre of administration within the Apartheid Governement, has with no doubt been altered, adapted and rennovated to accommodate the communities needs. The new Greenshops Financial Services Centre has mirrored Oliver's views and quarried the ruins of the old buildings on the site and used local materials and skills which may have been considered inadequate, in the past and possibly even in the twenty-first century, to contribute to the communities' social development.

3.1.1. Sustainability

The critical need to raise public awareness from the Centani Greenshops Financial Services Centre intended to set in motion the healing of all parts of the social body, using as few as possible of the earths resources and 'planting' in the community an ethos of indepndence. This project characterises sustainability unerringly, giving it significance that far exceeds its size, as a model for architectural method which engages the unique problems in this country and as a model for sustainable development.

Summarizing what Lawrence (2006, p. 122) presented regarding the "basic principles for professional practice" one of the principles which dealt with 'adaptability' of the existing building stock for the reuse of old buildings to serve the needs of contemporary daily life – has been successfully practiced in the the Centani Greenshops Financial Services Centre project. Today, the principle of adaptability is too easily forgotten by architects - who want to demolish, rather than renovate existing buildings. Lawrence went further stating that 'there is a need to consider how to reduce uses of non-renewable resources, how to lower greenhouse gas emissions and lower solid waste disposal,' thereby gratifying the sustainable principles of design.

The materials used within the project allowed for unparalleled flexibility: old bricks from quarried buildings were reused, the newly built forms can be recycled or left to decompose back to the soil. Overall, the Greenshops Financial Services Centre should be celebrated and promoted in light of these economic and ecological attributes, both of the latter which are also noted by Marchand (2006, p. 61).

The Centani Greenshops Financial Services Centre reflects the meaning of sustainability through every facet of the project. Ecological and cultural diversity is mirrored through the consistent use of local materials suitable to the environment. Ruined buildings' materials were reused , particulary bricks; the abundance of clay from the excavations, suitable for building as well as thatching grass needed to reinforce the mud walls; roof eves were extended to provide weather protection. The buildings are designed to maximize passive heating and cooling using shading devices, raised floors and variable ventilators. Rainwater was taken off its roofs to strorage tanks to be used in the permaculture gardens (Cooke, 2009. p.22-26).

3.1.2. Vernacular Architecture

The Centani: Greenshops Financial Services Centre has been in use for two years and although still young, has convincingly proven that the traditional methods, vernacular forms, indigenous building methods and locally sourced material, can be put back into contemporary building use. The commitment from the architectural team to make use of local resources - an approach long espoused - was rewarded by the community's continuous appreciation and independence in every sphere which proved to be exceedingly affirming (Cooke, 2009. p.22-26).

As discussed previously and also noted by Oliver, Lawrence, Ozkan, AlSayyad and Asquith (regarding the principles of vernacular architecture), the Greenshops project successfully inculcates vernacular principles: built by the local people of Centani; with available resources from the site and town; utilizing a variety of traditional technologies; built to accommodate and meet the specific needs; and finally accommodating the values, economies and ways of living of the local culture that produced it. Within the context of vernacular architecture the project has embraced what is known and what is inherited about the building. It has included the collective wisdom and experience of a society and the norms that have become accepted by the group as being appropriate (Oliver, 1986, p. 113).

3.1.3. Tradition

Echoing within the Centani Greenshops Financial Services Centre is what Rapoport (1989) viewed as significant in the modern concept of tradition: where the past becomes part of the present as a guide to future action. Lewcock (2006, p. 16) added to the traditional concept of the latter, and the Greenshops Financial Services Centre project can easily be viewed as such: a process in which innovation and precedent are dynamically combined allowing continuous change to take place.

Perhaps the most interesting exercise conducted by the architects, this social development project aimed to encourage local people, and instilled once-again their appreciation of the traditional building methods of mud and earthen infill as the principal building material (Cooke, 2009. p.22-26). Earth construction used as a building material within this project has provided a real alternative for the building sector, its technical performances were established, and it provided an economically viable solution, both in macro-economic terms and in terms of building costs. It renewed the links with traditional building cultures, thus retaining its local nature, not only by virtue of the raw materials used, but also from a cultural point of view (Booysen, 2003, p. 43).

3.1.4. Indigenous Knowledge and Innovation

The Centani Greenshops Financial Services Centre successfully explored the relationship between local knowledge, available resources, cultural identity and architecture. More specifically, the project illustrated the gestation of technical learning and socialization that occurs throughout a project focussed on social development. As reasoned by Marchand (2006, pp. 46-47) that the indigenous knowledge of local building trades must be central to discussions, studies and projects concerned with the sustainability in the twenty-first century and beyond, each of the latter were addressed within the project.

Innovation was stimulated with the the traditional wattle and daub technology being improved by providing concrete foundations and by adding diminutive amounts of lime and boron-treated thatch to the the mud mixture, a concept applauded by Rapoport (1989) in which the past becomes part of the present as a guide to the futrue. Innovation was also reflected in the archtectural designs' ability to reuse the materials of ruined buildings – plundered bricks, which were cleaned off; broken, hard materials were used as aggregare in foundations, door handles fashined from the original jail bars were reclaimed from the site. These innovative ideas also aided in the sustainability of the project as a whole (Cooke, 2009, p. 22-26).

Encapsulating the values of the society surrounding the building, the architects decapitated the myths which surrounded the eucalyptus plantations' sounds - which were found to be wind-induced. The mysteriously encoded culturally determined symbols, which are usually only read through the acquisition of knowledge, which is frequently inaccessible to all but the privileged elite: to shamans, medicine men or priests, (Oliver, 1987, p. 170) were therefore decoded by the architects. The brave steps taken into the traditional belief systems, added to the strength of the symbolism: a bridge to the changes within, into a community meeting place and financial service hub (Cooke, 2009, p. 23-24).

The plantations became the primary source of training for the locals - who were set out to manufacture economically-sound eucalyptus and pine doors and windows. Local residents were trained to fell trees, strip and boron-treat the timber and cure it in a solar kiln for use in the structure as ceilings, screens and ventilators (Cooke, 2009, p. 23-24).

3.1.5. Apprenticeship

From the start, the Centani Greenshops Financial Services Centre recognized the local indigenous people as pivotal agents necessary for the implementation and long term success. Respect for the locals autonomy and regular consultations with the builders about the project aimed at scheduling, consequently strengthened the internal ties and coordinated efforts of the professional association. The project provided locals with valuable opportunity to acquire practical experience in restoring the old building and fostered skills that would hopefully be inculcated in successive generations of builders (Marchand, 2006, p. 50).

The transmission of knowledge and the negotiation of identities and boundaries that takes place through the system of apprenticeship have allowed the local people to sustain standards and has enabled them to continuously create a meaningful built environment within the region. Such a built environment is inherently dynamic, "while remaining rooted in a dialogue with history and place" (Asquith, 2006, p. 8). Crucially, this dynamism needs to be taken into account when considering the sustainability of the building tradition (Asquith, 2006, p. 8).

The Greenshops Financial Services Centre was developed beyond the mere site and the architects were well aware that the potential success of the project would be determined by the local skill - passed down through generations - and social acceptance of the new buildings. Workshops with local chiefs and cultural leaders, to include their perspective and needs in order to develop an appropriate approach were held, as well as in-depth studies of available materials and appropriate technologies to the area (Cooke, 2009. p.22-26). Knowing that materials can only be exploited when a society has the technology to work it and that good builders know their materials and make the best of their properties (Oliver, 1987, p. 59), the architects examined carefully the building technology which was currently in use, finding a mixture of traditional indigenous materials. With much experience and traditional influence, the entire workforce employed for the project were local Xhosa people who, according to Oliver (1987) had developed intuitive senses of appropriateness for the materials.

The value of participatory and apprenticeship approaches to the development also reflected in the gardens, which were to be used to produce food in the kitchen for the staff. This process also created work, seeded small businesses and transferred skills (Cooke, 2009, p. 23-24).

3.2. New Auditoria and Teaching Complex at the Fort Hare University:

The architects of the new Auditoria and Teaching Complex for the University of Fort Hare in East London - Ngonyama Okpanum Associates in association with Native Architecture - developed a 'pattern language' to regulate the design intent; this, inter alia, included all floors to be accessible for services, all buildings to be orientated with long facades facing north, limited air conditioning for apparatus only, naturally ventilated spaces, natural day-lighting, locally sourced materials and light-weight construction (Stratford, 2009, p. 54-57), the importance to achieve a state of pax deorum within the design seemed central although on further study, it may seem as though ira deorum is more prevalent.

The complex is bounded on the north and south by wide streets; the primary response was to place three wings running east west, in downward cascade from the south towards the north. Each wing is penetrated by a pedestrian concourse that is vertically connected by a lift in the south wing and a series of double-acting staircases at the intersection of each wing. This concourse starts on the street at parking level on the south side and spills out onto the street at second floor, which is at grade on the northern street. In this way, the concourse becomes a pedestrian arcade of the city (Stratford. 2009. p. 54-57).

2.2.1. Sustainability:

The New Auditoria and Teaching Complex at the Fort Hare University, has the entire building oriented with long facades facing north, natural ventilated spaces and natural day-lighting, and a wind scoop system which aims at regulating temperatures and internal conditions.

The sustainable principles delineated earlier by Hatfield Dodds (2000) and Lawrence (2006) have had modest regard within the New Auditoria and Teaching Complex at the Fort Hare University. The ecological considerations have been accounted for through the consented solar exposure given to each wing of the building, reducing the winter shadow. Unfortunately the value of participatory approaches to the development has not enjoyed the same significance which was given in the Centani Greenshops project. The critical need to raise public awareness of the sustainable issues concerned are however being addressed regularly by the architects. The economic activity on the site has not over-exploited natural resources due to the use of innovative Wintec precast concrete systems which minimized the use of commonly used concrete and also limited the amount of waste on the site.

The external façade to the south walkway is faced with a permeable mesh screen, which serves to rupture prevailing winds and alleviate driving rain. Inside this mesh screen is a vertical planting screen at each floor which is irrigated with harvested rainwater. This serves to provide evaporative cooling and oxygenation of natural air which is drawn into the building from the cooler side of the building; it also provides a 'handrail' to the walkway (Stratford, 2009, pp. 54-57). Despite the impressive ventilation systems used as temperature-sustaining tools, (as it continually cools the inside temperatures of the building) there remains one intrinsic flaw: the colder winter months have not convincingly been accounted for. The Latin word sustenere meaning to uphold, or capable of being maintained in a certain state or condition, is the origin of 'sustainability', therefore, while 'sustainable' can mean supporting a desired state of some kind, it can also mean maintaining undesirable conditions (Lawrence, 2006, p. 111) as is reflected in the continuous cooling of the building - despite the low outside temperatures.

3.2.2. Vernacular Architecture:

The New Auditoria and Teaching Complex at the University of Fort Hare is more than the materials from which it is made, the labour that has gone into its construction or the time and money that may have been expended on it: as borrowed from Oliver (1987, p. 15), the new complex as the theatre of the students lives where the major dramas of education and politics, of laws and policies, of labour and of being in labour are played out, and in which a succession of scenes of public and community life is perpetually enacted. Yet the metaphor unaccompanied remains derisory: the play can be performed without the stage; the theatre stands empty for most of the time, awaiting the performers and their audience. The New Auditoria and Teaching Complex at the University of Fort Hare within the city centre of East London (as a contemporary South African building) is more than just a stage or a scene; the relationship of each individual to the building is innate and essential for the growth of a mutualitarian country or society. Whether this relationship will exist within the building is still to be examined. The lack of ownership which should be instilled between the building and its inhibitor during the community's participatory and apprenticeship systems is a large setback which can be measured only after completion.

Vernacular architecture should also include available resources and a variety of traditional or innovative technologies, the choice of laminated saligna timber for all joinery within the building was an informed decision made so as not to import exotic hardwoods or aluminium extrusions, the timber was locally sourced and after lamination still remained cheaper than meranti timber (Stratford, 2009). Unfortunately, one would be mendacious to state that the building is justly vernacular. For this building to be truly vernacular, it will have to be part of a cultural context that, in contemporary South African times, is ever harder to find (Vellinga, 2006, p. 88) – it would mean that the building is accommodating the values of the local people, economies and ways of living of the cultures that produce them, which to date has not yet been motivated.

3.2.3. Tradition and innovation

In the writings of Bronner (2006. p.6) tradition is about expectation and social acceptance rather than constraint. As a reference to precedent and a social construction, tradition invites commentary and interpretation and is often continuously re-negotiated, from generation to generation. As such it allows for creativity, adaptations and innovations that may ultimately, once they have been socially accepted, be integrated and become part of the tradition. It is this tradition used within the New Auditoria and Teaching Complex at the University of Fort Hare, which needs first to be socially accepted prior to a final triumph being realized.

Within the New Auditoria and Teaching Complex at the University of Fort Hare, the social acceptance is tested by the expectations of the design. Innovative ideas and extreme engineering stretched the negotiation within the innovation to be accepted into social tradition. The tremendous innovations can be found throughout: air being drawn into the innovative Wintec Ventilated Access Floor through special floor-mounted diffusers by virtue of displacement ventilation within the interior space; the north façade is double-skinned and is ventilated at the roof apex; this north façade is made up of black recast concrete panels, U-shaped in plan and glazed across the U to form a vertical flue, the combination alternates with an internal glazed timber façade which is opposite a flush glazed façade spanning between the precast panels. In this way, another vertical flue is formed between the two glazed facades. Also, the internal reveal of the precast panels is splayed and painted white; this together with vertical reflective Venetian blinds within the flue spaces controls bounced light into the interior. The ventilation system is powered by solar energy through buoyancy induced in the ventilated stack façade and also by wind-induced pressure differences generated at the aerofoil section covering the continuous apex roof slot (Stratford, 2009, pp. 54-57).

The analysis of tradition within this environment takes on the life story of the creators and the symbolism of the expressions. Unlike the ideal of vernacular as the prevalent common expression of the people, most of the future students will be well aware that they stand apart in this elaborate structure. It is also expected on completion of the project that interviews with the inhabitants will draw out their reference to grassroots skills and processes that are not, but should have been, part of this modern culture (Foster, 1984).

3.2.4. Indigenous Knowledge and Innovation:

As in other similar instances when architects attribute innovative forms and ideas to particular buildings it was not so much the historical veracity which was of interest, but rather the degree of esteem they accorded to creativity and signature in the building trade (Marchand, 2006, p. 56). Rather than the use of indigenous knowledge, innovative concepts were tested, stretched and implemented: the ventilated access floor, a new concept which provides a floor plate with access from top and bottom, a plenum for services and ventilation all within a structural depth of 535mm; the floor is finished on both faces with precast concrete floor/ceiling tiles which provide a heat sink and are fitted with service access points for power and lighting; the all-up mass of this floor is 45% less than equivalent in situ access floor - which would be about 850mm deep - in this way the embodied energy is dramatically reduced by brining less material to site and the floor may be deconstructed and built into another project at the end of the building life cycle (Stratford, 2009).

Although one could never insult the innovative genius in the wake of the New Auditoria and Teaching Complex's design, the query made by Bronner (2006. p.6) still remains in the hindsight: adaptations, innovations and the social acceptance thereof are all endorsed through the invitation of commentary and the renegotiation of tradition and indigenous knowledge, both of which are currently being regarded with some hostility.

3.2.5. Apprenticeship:

Apprenticeship systems are dwindling as the indigenous cultural know-how of traditional building methods decline. The impacts on the layout and construction of the built environment, plus the consumption of materials and energy have increased significantly. Today, there are choices between traditional materials and methods, synthetic materials and new technologies: the former usually enables the use and reuse of renewable resources, where as the latter require more energy and more specialized expertise (Lawrence, 2006, p. 127).

Although there is a reduction of embodied energy within the precast floor/ceiling tiles, less wasted material on the site, and the materials ability to be deconstructed and reused - these materials still require more energy than traditional materials and methods. The specialized expertise needed for the construction of the building, the lack of apprenticeship systems and of community participation all lead to the reduction of the sustainable roots surrounding community and economic upliftment as well as the ability for the community to take ownership of the building.

4. Comparative analysis:

Sustainable adjustments to climate, which were considered in both case studies, were the influence of the angle of the earth's axis to the sun, the direction and speed of its rotation, irregular and unequal distribution of land masses, differences in atmospheric pressure, energy received from the temperature from solar radiation and that radiated into the atmosphere, types and densities of vegetation, the patterns of precipitation, prevailing winds and ocean currents (Oliver, 1987, p. 116). The East London region within the Eastern Cape Province of South Africa may be summarised as a temperate or humid mesothermal and sub-tropical climate. The New Auditoria and Teaching Complex was built to serve a variety of functions to accommodate various faculties as the different departments moved through the available space as it became available (Stratford, 2009), but one of the most important efforts within the project was to create a "micro-climate" acceptable to their occupiers.

Buildings, according to Oliver (1987, p. 113), do not control climate, which apart from the wind or shadow that they may cast, remains largely unaffected by them, but within the building, it does modify the climate, creating internal conditions that come closer to those which the occupants find most comfortable. Creating or designing according to human comfort could and should use means and methods which are not detrimental to the environment in order to allow the inhabitants to respond to their prevailing climatic conditions as has been exercised within both the Greenshops Financial Services Centre and the New Auditoria and Teaching Complex at the Fort Hare University.

Vernacular resources, technologies and forms such as adobe, wind-catchers or courtyards are generally seen to be well adapted to local climatic conditions and are therefore often considered as appropriate bases for environmental design – as has been established in the Centani Greenshops Financial Services Centre. What is needed however, are methods which enable the systematic test of the actual performance of vernacular traditions and to thereby generate an understanding of how they may be upgraded so as to provide truly sustainable buildings for the new millennium. Although both Centani Greenshops Financial Services Centre as well as the New Auditoria and Teaching Complex at the University of Fort Hare where well considered with regard to vernacular architecture, it remains difficult to comparatively analyse the project within the vernacular framework. One method tried while determining the vernacular performance of each project was in situ monitoring – these results aimed to show the projects which have been 'counter-intuitive' in the sense that the buildings did not perform as well as generally assumed. What is needed within the vernacular architecture of South Africa then, is research that critically tests the performance of vernacular traditions in the face of the challenges of the twenty-first century.

The Centani Greenshops Financial Services Centre, in addition to its social and technological concerns, materials and methods of construction were developed that took into consideration the scarcity of natural resources. Innovative and appropriate technologies were developed based on abundant and readily available natural materials. Moreover, in order for the project to be successful in the long run, thorough training programmes for local builders were regularly implemented (Cooke, 2009, p. 22-26).

As early ethnographies predicted in previous historical projects, the University of Fort Hare design has succumbed to the pressures of modernization and development: the design has adapted the building culture by incorporating primarily modern elements, rather than maintaining and even strengthening traditional others (Vellinga, 2006, p. 85-86). Part of the resistance which one expects to occur, is also stemmed from the fact that these innovative solutions have been brought in by "westerners", even though the project employed local resources. The University of Fort Hare's new building closely resembles the Village of New Gourna in Egypt by Hassan Fathy (Fathy, 1973). Both are well-intentioned and good-willed, but failure is presented through the fulfilment of architectural goals because of pre-existing, complex cultural forces that emanated from within the local community.

Under such innovative circumstances, it is in testing to be successful. First of all, it is impossible to objectively select the criteria that define the term 'success'. Is the measure of success the number of lecture rooms provided for students? Is it the student's acceptance of what has been offered to them? Or is it the students own definition or expectation of a lecture theatre?

Linking the indigenous knowledge system observed within the Centani Greenshops Financial Services Centre, with world science and innovations (the New Auditoria and Teaching Complex at the University of Fort Hare) requires better understanding of both the role of scientific (architectural) research and the limits of empirical locality-specific indigenous knowledge (Ezaguirre, 1992, p. 20). There should exist no fissure in the relationship between indigenous knowledge and scientific innovation. If South African Architecture is to mean more than the mere provision of yet another roof and wall to the populace; there needs to exist a greater understanding about the qualities that shape the publics needs within a building. By doing so, the architectural practice may be more effective in designing buildings appropriate to indigenous living conditions and public needs – and within this process learn more about our country's wealth of knowledge and innovative solutions to current problems.

The Centani Greenshops Financial Services Centre has essentially adopted the importance of local technical and historical methods of construction by including an apprenticeship system together with innovative modern techniques, thereby adding to the community a unifying sense of ownership and responsibility. The New Auditoria and Teaching Complex at the Fort Hare University has taken a wider approach by creating innovative developments in material mixtures and methods of construction (rather than the training of people about the actual construction thereof), value is therefore weighted primarily on engineering ingenuity rather than on community upliftment.

All buildings, whatever their function, have to meet certain physical constraints. The Centani Greenshops Financial Services Centre was the result of a long tradition of received techniques, assembled by trial, error and experimentation over many generations. The New Auditoria and Teaching Complex at the Fort Hare University was based on detailed mathematical and engineering calculations and the application of formulae after experimentations. Neither is better nor worse than the other, as the basic laws of physics ultimately determined whether either building will stand up or collapse (Oliver, 1987, p. 57).

5. Closing Remarks:

As was noted by Ezaguirre (1992, p. 19) and also verified within the case studies, local indigenous and technical knowledge within the building practice should never be overlooked. Local peoples' knowledge about the specific conditions in which they live and work may be more exact than the knowledge of practicing individuals in the building profession. This is neither a failure within the building profession nor the idealization of the low-resource area, but recognition of the division of labour between architectural research and the empirical knowledge that local indigenous people acquire in order to produce with available resources.

As is revealed within the case studies, an approach which focuses on the active application of vernacular technologies (Fathy, 1973), forms and resources in a modern and development contexts will not be without its problems, challenges and setbacks, and will have to address themes and issues that so far have been largely disregarded in the field of vernacular, indigenous and sustainable studies. For instance, as it will have to engage with, or indeed be part of, the so called 'development discourse' (Grillo, 1997), there will be need for critical discussions of the political and ethical dimensions of key concepts like sustainability, development, intervention and participation.

There already exists a long established, though still somewhat marginalized discourse that focuses on the ways in which indigenous traditions and innovations may be integrated into contemporary building practices, as was summarised by Afshar and Norden (1997). At present however, while concerns over sustainability and cultural identity continue to shed animosity over the processes of modernization and globalization, an alternative, innovative approach to development is continuously being looked for. It seems more opportune and urgent a time than ever to fabricate the achievements of such research into contemporary practice.

Unfortunately, as was noted by Payne (1977), and confirmed within both case studies, western models of planning and designs based on commercial land markets are penetrating most parts of our country. Perhaps rural areas less so as was shown by the Centani Greenshops Financial Services Centre, but finding ways in which vernacular knowledge and expertise may be integrated into urban contemporary building design and practice continues to be one of the main challenges one faces in the twenty-first century.

What is needed is the disposal of the stigmas of underdevelopment, poverty and the past that currently cling to the concept of indigenous vernacular architecture. Such research and education should focus on issues of process rather than product, identifying general principles and concepts rather than basic facts and figures. More importantly, it should be critical and actively engaged in realities of the present, rather than remaining focussed on the past. These ideals were further emphasised by Rapport (2006), however, in order for the sustainable, innovative, indigenous and vernacular architecture to teach lessons that are relevant to the future, a more problem-orientated, comparative and integrative stage that leads to explanatory theory needs to be entered.

The New Auditoria and Teaching Complex at the University of Fort Hare has become a precedent from which much may be birthed, traditions have allowed for creativity, innovation, and change; building traditions continue to evolve and transform while new ones will arguably keep emerging. Though such new "grassroots traditions" may not be as established as that of local earth construction, it may well represent the future of the sustainable and vernacular in industrialized urban societies.

The patterns and principles of good practice from both the Greenshops Financial Services Centre and the New Auditoria and Teaching Centre and the New Auditoria and Teaching Complex at the University of Fort Hare were identified to sustain the human settlements for which they were designed. Building design and construction together with the layout of the buildings were explicitly account for: water cycles that collect and reuse rain water and grey water in buildings and adjoining open spaces; natural ventilation in contrast to mechanical systems of air-conditioning; reusable materials, such as wood, clay and brick, should be used instead of non-biodegradable synthetic products in new building construction and renovation projects. Innovative approaches of this kind not only help promoting the local architectural environment, but also protect the cultural heritage of human settlements (where applicable). In addition they have become a catalyst for a new kind of ecology-orientated tourism and economic investment (Lawrence, 2006, p. 124).

Participatory approaches should become an integral component of the building culture, as well as development initiatives which aim to promote and establish sustainable supplies of locally available building materials (Marchand, 2006; Lawrence, 2006). Local appreciation for traditional Eastern Cape architecture and building methods must be bolstered, and it's social, economic and ecological value recognized. The post-colonial dichotomy between tradition and modernity must be challenged along with the popular association of tradition with stasis and 'backwardness' and the conceptual affiliation of modernity with concrete, corrugated iron and all things Western must be debunked. Changing attitudes can only be achieved through educational processes that promote scholarly investigation, publications, public displays and open discussions (Marchand, 2006).

Pressure (on architects to design contemporary, truthful, honest and socially acceptable buildings) comes primarily from the local market. In an urban setting of South Africa, contemporary, modern and "western" architecture command a considerably higher market price and social acceptance than do the traditional rammed earth or compressed earth blocks mixtures. As long as the South African elites continue to conceive of mud architecture as the property of their poverty-stricken rural brethren, the Xhosa-building tradition within the Eastern Cape, as well as the diversity of other building traditions and innovative designs throughout the county, will be progressively denigrated and may one day cease to exist (Marchand, 2006; Voss, 1992).

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The Role of Innovative Technology in Sustainable Human Settlements

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Introduction

The construction industry, which comprises both the building (residential and non-residential) and civil engineering sectors, produces physical infrastructure that alters our natural and built environment landscape. However, environmental concerns including climate change are rapidly changing the operating environment and, like other big industries, construction is expected to develop and implement the prerequisite adaptation and mitigation strategies.

Global construction demand is being driven by a steadily growing urban population (especially in developing countries) giving rise to chronic housing shortages, inadequate and failing infrastructure, devastation arising from natural and human-induced extreme events, and signs of emerging environmental distress. The global population grew on average by 81 million people annually between 1975 and 2009 (UN, 2008): enough to fill a region the size of Gauteng every two months. Since cities are not under construction at this rate, existing urban infrastructure has to absorb an additional 200,000 people every day. An estimated 900 million are living in inadequate housing and unsafe neighbourhoods. Individuals and families struggle to secure the resources they need for healthy and prosperous lives and this includes shelter (IIED 2009). There are very high levels of informal tenure and incremental housing development in towns and cities in developing countries: urban poverty is a significant cause of inadequate shelter.

The Millennium Development Goals are the world's time-bound and quantified targets for addressing extreme poverty in its many dimensions – income poverty, hunger, disease, lack of adequate shelter, and exclusion – while promoting gender equality, education, and environmental sustainability. They are also basic human rights – the rights of each human being to health, education, shelter, and security as pledged in the Universal Declaration of Human Rights and the UN Millennium Declaration (UNDP 2005:1). The UN Millennium Goals are interpreted as country goals: that is to say they must be made operational by the individual sovereign state, and the state must be held accountable as a co-signatory.

Regrettably the number of people living in slums and slum-like conditions in the world's cities is growing: between 1990 and 2001 the slum population grew in every region except North Africa (UNDP 2005:19), and in many instances, the quality of existing shelters are "deteriorating" (UNDP 2005:2). For all developing countries the UN recommends that the MDG-based frameworks to meet the 2015 targets be designed around seven "clusters", one of which is "Promoting vibrant urban areas, by encouraging job creation in internationally competitive manufactures and services, upgrading slums, and providing alternatives to slum formation" (UNDP 2005:64). The UN Millennium Project recommends that known interventions reaches the scale of investment needed to achieve the goals. The need to scale up arises from the limited impact of pilot projects implemented at local or district levels without a measurable impact on national indicators. National scale-up however remains a major institutional challenge requiring an intersectoral approach and a carefully designed multiyear planning framework.

Progress toward achieving the Millennium Development Goals has been slow in Sub-Saharan Africa: one of the reasons for this is the "very slow diffusion of technology from abroad" (UNDP 2005:148). An essential priority for African economic development therefore is to mobilize science and technology targeted at Africa's specific ecological challenges, i.e., food, disease, nutrition, construction, and energy (UNDP 2005:156).

South African Context

Within the South African context, the South African population was recorded in the 2009 Community Survey as 49 383 thousand with the total number of households recorded as 13 812 thousand. The net population growth was recorded as 430,000 per annum.

Government's aim is to deliver 220,000 subsidised houses per annum between 2010 and 2014: the current backlog for state subsidized housing as of 2010 was reported as approximately 2.1 million which translates to about 12 million South Africans still in need of a better shelter (Sexwale 2010). Government has budgeted R16-billion on subsidized housing for the 2010/2011 financial year. Fifty six per cent of households lived in formal dwellings in 2009 (StatsSA 2009:5) with 13,4 per cent of households living in informal dwellings. The number of households living in 'RDP' or state subsidized dwellings was recorded as 12,8 per cent with an almost equal percentage of households having at least one member of the household on a demand database/waiting list for state subsidized housing.

Of those occupying RDP or state subsidised housing 16,1 per cent stated that the walls were weak or very weak and 14,9 per cent regarded their roofs as weak or very weak. More than 30 per cent of households in the Western and Eastern Cape reported problems with the quality of the roofs and walls (StatsSA 2009:5).

With regard to other infrastructures services, 82,6 per cent of households are connected to the mains electricity supply: however, 24,8 per cent (or one-in-four) of households still use wood or paraffin for cooking. While 89,3 per cent of all households had on- or off site access to piped or tap water, only 42,1 per cent accessed their main source of drinking water from inside their dwelling. With regard to sanitation and waste removal, 6,6 per cent of households had no access to a toilet facility or were using a bucket toilet and 46,9 per cent of households do not have their refuse collected by the municipality.

Definition of Terms

Building performance – means the physical performance of the building components and of the building as a whole in terms of structural stability, durability, water penetration, wind and condensation resistance, and thermal, acoustic and lighting comfort.

Built environment – shall be defined as that environment which comprises urban design, land use and the transportation system, and the patterns of human activity within this physical environment (Handy, Boamet, Ewing and Killingsworth, 2002).

Environmental performance – means the degree of physical human comfort or discomfort inside a specific space.

Feasible – potentially achieve-able, considering none, or very little, additional cost, the limitations of available labour, training that may be required, ease of maintenance and robustness and local availability of materials and components for later alterations and additions.

Finishes – means the surface treatment of building components or elements, such as paint to walls and ceilings, carpets or tiles to floors and the treatment of surfaces, such as wood or stone.

Fittings and fixtures – means attachments to the building and its elements which, while fittings remain loose and detachable from the building, fixtures are mechanically fixed to the building and can only be removed by mechanical means.

Foundation – is that part of walls, piers and columns in direct contact with, and transmitting loads to, the ground (Emmitt & Gorse, 2005).

Implementable – means buildable and useable within the context of low-cost housing.

Infrastructure – in the context of this paper is defined as the basic physical assets of a country, community or organisation. These assets are usually referred to as fixed assets (e.g., buildings, highways, bridges, roads, pipelines, water networks, rail tracks, signals, power stations, communication systems, etc.) and moving assets (e.g., aircraft, train rolling-stocks, defence equipment, buses, etc.) (Ciria, 2007).

Innovative technologies from Science, Engineering and Technology – materials technologies, manufacturing technologies, production technologies and assembly technologies that are science based or supported, or enhanced by science, engineering and technology and that improve building performance.

Less dependant on municipal services – where municipalities cannot always meet the service needs of new housing areas falling within their jurisdiction, individual houses or groups of houses can be made less dependant on such services by supplying, or partially supplying, their own service needs in terms of water, sewage, water heating and drainage in a sustainable manner.

Low-cost housing – means houses developed by a Local Authority using a government subsidy.

National Building Regulations – means those regulations promulgated in terms of the National Building Regulations Act (Act of 1970).

Open Building Approach – in the context of the paper means not closed or blocked up, allowing entrance or passage or access to all irrespective of colour or creed or kin, inclusive not exclusive, accessible to the physically handicapped, multi-usable, extendable, demountable and re-locatable.

Optimally applied – the gains of applied innovative technologies optimised or maximised in terms of performance and affordability.

Poverty reduction – considering the urban implications of optimal sustainability planning rather than that of a single house/stand, small industry and local labour opportunity can be created, together with subsistence food gardening. Group servicing of properties and waste disposal, sorting and sale are other possibilities, including prefabricated building components in a small local site workshop.

Roof assembly – is the structural support system and the fixing and securing mechanism for the roof surface material, which in turn is to cover the building and protect it from the weather. The roof assembly and finishing has to withstand the ravages of rain, snow, hail and wind, and large diurnal variations in temperature while moderating external conditions for indoor comfort.

Scientifically determine – by building, monitoring, and testing the houses as compared to acceptable standards and best practice. A scientific process by which defects can be determined and interventions considered and tested until healthy and sustainable conditions can be achieved.

Sub-structure – means those portions of the building below the finished floor structure, i.e., foundations and foundation walls or column supports, including any structure below top of the ground floor slab.

Subsidy houses – refers to the standard 40 square metre subsidy house type plan as approved by the NHBRC and built by developers and contractors across the country.

Suburban house – refers to a typical city suburban residential area of middle-income homes, inland from the coast on the Highveld of the country, boasting a mild climate, but with large diurnal variations in temperature.

Super-structure – means those portions of the building above the ground floor slab.

Sustainable living environments – means living environments are such that buildings impact minimally on the environment and attempt to put back as much into the environment as taken from it. Furthermore, the environment created by the building on the site in its local surroundings should form a sustainable entity. The building should be durable and easy to maintain, preferably by the owner or tenant and the building should be able to respond to occupant needs. The developments should, at least in part, be self sufficient and independent of municipal services and allow for a range of life situations.

The Technology Challenge

Technology significantly influences human's ability to adapt to or take control of their environment: application of technology may have both positive and/or negative results, and often causes unintended consequences.

Technology can be described as the state of practical knowledge and tool use at any given point in time. Technology encompasses arts, crafts, professions, applied sciences, and skills. It can also refer to systems and methods of organisation including the specific fields of study concerning them or the products that arise out of them. By extension, technology includes a collection of techniques: it encompasses therefore the current state of humanity's knowledge of how to combine resources to produce desired products, undertake problem-solving, fulfil needs, develop and implement technical methods, develop skills, and how develop new processes, tools and raw materials.

Alternative technology or technologies refers to various methods and practices used in place of, or as well as, conventional methods and practices. In building, alternative technologies generally refers to non-traditional building practice that does not fall within the realm of conventional building practice for that time or place or both. Thus whereas adobe construction is not alternative for certain rural areas, it would be considered alternative if used in an urban context.

Innovation can be described as the useful application of new inventions or discoveries (McKeown 2008). Innovation may be incremental or radical: the application must always be substantially different (not necessarily new) to be described as innovative.

Innovative Technology Challenge

The overarching challenge for innovative technology in housing can be stated as follows:

Guiding research question:
How, and in what way, can innovative material, production and assembly technologies in science, engineering and technology (SET) be applied to construction manufacturing to improve building performance, and construction processes, and facilitate sustainable human settlements?

The emphasis of the research question is on how innovative technologies can interact with the system that constitutes the physical built environment and how this system interacts, in turn, with the natural system. However, the solutions developed would be guided by an overarching set of principles, namely:

- Would the technologies developed and implemented improve the quality of life for the communities in which they are implemented through the following:
    - Providing a healthy living and working environment; and
    - Providing opportunities for economic development and sustainable livelihoods?
- Would the technologies developed and implemented contribute to sound ecological management principles?

Innovative Technology Objective

The objective of implementing innovative technology is to achieve comfortable subsidized housing that perform as good as or equal to conventional suburban housing, are durable and quick to build, readily alterable, easily extendable, less dependent on municipal services, and able to facilitate sustainable human settlements.

Constructing an Innovative Technology Framework

An innovative technology framework should be predicated on supporting certain key national objectives:

i) **Treat Development Holistically** – any technology proposals recommended for a housing project should be treated holistically, that is to say, that all proposals support a common set of national goals and objectives. Certain technologies are known to offer other benefits, such as job creation. Similarly, potentials to be found in the specific geographic conditions of the site and its surrounding areas, for example local soils, may well add-value to the development if properly exploited. Local authorities are increasingly unable to sustain the expansion of urban areas within their jurisdiction: thus, if any development proposal is to serve as a model development, it must demonstrate an ability to operate in a manner that will not further undermine the financial sustainability of local authorities. One of the ways that it can do this is to reduce the dependence of the development on municipal services. This approach should be explored at the level of the entire development, and not only at the level of individual housing units.

ii) **Scaled-up technology** – technologies employed should be capable of being scaled-up across similar subsidized housing projects in South Africa. The development of innovative technologies should therefore have in mind the skills levels within the construction industry, the needs of the beneficiaries, and the ability of the local authority and the community to service and maintain those technologies over time. The use of innovative products should similarly ensure that the technology solution be available to the beneficiaries over the life cycle of the dwelling.

iii) **Assess the impacts** – one of the objectives of the Department of Science and Technology (DST) is to improve the quality and depth of Science, Engineering and Technology (SET) statistical information to support development and investment decision-making as well as to drive improvements in the quality of SET activities against the backdrop of internationally recognized benchmarks. To accurately assess the impacts of the proposed technologies requires that a base technology level be determined in conjunction with alternative technologies, and that the technology be applied in the same manner. In other words, occupancy rates and occupancy usage should, as far as possible, be comparable. As stated above, certain technologies are more effective at certain scales than others: thus, the overall development must be assessed for scale opportunities and all technologies assessed against the range of scales offered within the development.

iv) Reduce extreme poverty – virtually all countries face critical decisions about the best strategies for managing the massive transition anticipated in the coming decades of rural populations out of agriculture. Challenges that this presents are related to determining how urban growth can be made more effective for poverty reduction and how new forms of urban growth can be captured cost effectively. Development technologies that support job creation, are labour intensive, and create opportunities for skills development and training are among the strategies that can support economic growth opportunities for urban communities.

v) **Explore global incentives** – climate change and global warming have stimulated new opportunities in the field of alternative energy technologies, especially those that reduce carbon emissions. The scale of this development may well meet the requirements for carbon trading with a developed country.

Innovative Construction Technologies

This section describes innovative construction technologies which could be considered for use in the design and construction of sustainable human settlements. The technologies are arranged into the same descriptive format as used for the experimental houses, namely sub-structure, super-structure, roof assembly and services.

The information is drawn from the experimental work done with the test houses, as well as the technology pillars and technology focus areas described in the PG Report Establishing an advanced construction technology platform for South Africa (CSIR 2007).

In the 2007 report, five technology pillars were identified, namely:

- Conventional technologies
- Fringe technologies
- Hybrid technologies
- Bio-technologies
- Nano-technologies

Conventional technologies are those technologies generally used by the building industry in contemporary building. It is based on most of the construction materials delivered to site in their raw or semi-raw state (cement, stone, sand, bricks), and the preparation and installation of the materials and/or products (wet and dry) done on the site. and/or products (wet and dry) done on the site.

Fringe technologies are those technologies that are reasonably well established, but whose application is generally low. Examples of fringe technologies include timber-framed buildings, lightweight steel buildings, solar water heaters and photovoltaic panels.

Hybrid technologies are those technologies that combine two or more technologies into the building process. Examples include polystyrene blocks with concrete infill or a light structural frame combining a panelised internal finish with a conventional external finish, such as traditional brick cladding.

Bio-technologies are those technologies relying on bio-materials for their composition. Examples of bio-technologies include natural fibre composites using natural fibres in concert with bio-resins or man-made plastics.

Nano-technologies are those technologies that work with molecules at a nano-scale. Typical examples would include a natural fibre composite where the fibres have been modified at the nano-level.

Both the bio-and nano-technologies are still too far away from implementation for consideration in the proposed laboratory building. These technologies will, however, need to constitute the next generation of construction materials if the massive consumption of non-renewable materials is to stop. For now the technologies under consideration will be drawn from conventional, fringe and hybrid.

The CSIR PG Report of March 2007 *(Establishing an Advanced Construction Technology Platform in South Africa)* also identified five material focus areas, namely light steel technology, light concrete technology, composite technology, Open Building Manufacturing Systems and convergence technologies.

Light steel technology

Among the report's recommendations, the following Research, Technology and Development (RTD) activities can be included into the design and construction of sustainable human settlements:

- Load-bearing thermal-stud walls for external walls; and
- Light-weight steel-joist floors.

Light concrete technology

For the purposes of designing and constructing sustainable human settlements, use can be made of 50mm continually reinforced concrete pavement (CRCP) for ground floor slabs, for the roof as a thin concrete composite, while permeable concrete pavement can be further used for external parking areas.

Composite technology

The identified technologies in this focus area are not ready for immediate implementation and will require ongoing research. However, under investigation are natural fibre composites roof sheets and sections.

Open Building Manufacturing Systems

Open Building Manufacturing Systems (OBMS) is more of a construction process than a construction technology; however, it requires a specific technology response in order to fulfil its objectives. OBMS incorporates the application of contemporary systematised methods of integrated life cycle design, production planning and control, mechanised and automated manufacturing processes, and lifecycle management and maintenance. Included in the OBMS approach are the following: *Concepts for manufactured buildings* – included in this area is flexible system typology with rich architectural expressions, flexible manufacturing and mass-customisation options; smart components with integrated services, and smart connections enabling rapid, easy, ‘plug and fix’ assembly on site.

Business processes – included in this area is performance-driven production and delivery processes supported by assessment methods and coherent indicators for whole buildings, new value-driven business processes specifically for open manufactured building systems, organisational concepts and models to support and reflect new processes, and new services covering the whole life cycle of buildings.

Production technology and automation – included in this area is off-site manufacturing and preassembly: highly flexible, scalable, efficient, and automated manufacturing methods systems including robotics, mobile factories and concepts for portable/mobile factories that will bring efficient manufacturing and preassembly operations to building sites, logistic solutions for efficient and lean handling and on-time delivery of modules and components and on-site assembly methods and systems for rapid, safe and precise handling and assembly of modules and components.

Information and communication technology – research areas required include distributed, web-based, intelligent component catalogues; customer-driven, three-dimensional model-based, design and configuration; and model-based, site logistics and assembly planning.

System integration – areas requiring further research include open versus closed systems and integration of products, processes, life cycle support and information.

Convergence technologies

Technological convergence is the modern presence of a vast array of different types of technology to perform very similar tasks. Thus, convergence technologies refers to a trend where some technologies having distinct functionalities evolve to technologies that overlap, i.e., multiple products come together to form one product with the advantages of each initial component. A classic example in construction is fibre reinforced concrete. Roco and Bainbridge (2002:10) identify four areas for fundamental scientific research that will have great significance for technological convergence. Two of these have relevance to construction, namely:

Entirely new categories of materials, devices and systems for use in manufacturing, construction, transportation, medicine, emerging technologies and scientific research – nanotechnology is clearly pre-eminent in this regard, but Information Communication Technology (ICT) also stands to play a significant role in both research and design of the structure and properties of materials. Included in this area are adaptive materials such as house paints that change colour, reflecting heat on hot days Dianne Panel Beaters is a family owned company with over a decade of experience.

Established in the late 90’s it’s one of the leading panelbeating company’s located in Pretoria West. Our qualified staff are equipped to ensure a wide range of autobody repair. We are also BEE compliant.

Fundamental principles of advanced sensory, computational and communications systems, especially the integration of diverse components into the ubiquitous and global network – a particularly challenging set of problems confronting computer- and information-science engineering is how to achieve reliability and security in a ubiquitous network that collects and offers diverse kinds of information in multiple modalities, everywhere and instantly at any moment. In a rapidly changing global environment, sensing the environment and bio systems will become essential in global environmental monitoring and remediation (Roco & Bainbridge 2002:17).

Principles of Sustainable Design

While the practical application varies among disciplines, some common principles include:

- Low-impact materials: choose non-toxic, sustainably-produced or recycled materials which require little energy to process.
- Energy efficiency: use manufacturing processes and produce products that require less energy.
- Quality and durability: longer-lasting and better-functioning products will have to be replaced less frequently, reducing the impacts of producing replacements.
- Design for reuse and recycling: "Products, processes and systems should be designed for performance in a commercial 'afterlife'".
- Design impact measures for total earth footprint and life-cycle assessment for any resource use are increasingly required and available. Many are complex, but some give quick and accurate, whole-earth estimates of impacts.
- Sustainable design standards and project design guides are also increasingly available and are vigorously being developed by a wide array of private organisations and individuals. There is also a large body of new methods emerging from the rapid development of what has become known as 'sustainability science' promoted by a wide variety of educational and governmental institutions.
- Biomimicry: "redesigning industrial systems on biological lines ... enabling the constant reuse of materials in continuous closed cycles..."
- Service substitution: shifting the mode of consumption from personal ownership of products to provision of services that provide similar functions, e.g., from a private automobile to a car sharing service. Such a system promotes minimal resource use per unit of consumption (e.g., per trip driven).
- Renewability: materials should come from nearby (local or bioregional), sustainably-managed renewable sources that can be composted (or fed to livestock) when their usefulness has been exhausted.
- Healthy Buildings: sustainable building design aims to create buildings that are not harmful to their occupants or to the larger environment. An important emphasis is on indoor environmental

quality, especially indoor air quality.

Case study

Background

This case study arises out of a request made by the Department of Science and Technology (DST) to CSIR in 2007 to evaluate two applications for funding made to DST with regard to subsidized housing projects. The applications were submitted by Overstrand Municipality and Buffalo City Municipality for additional funding for 711 and 500 houses respectively. The CSIR in its Evaluation Reports of September 2007 noted that both applications offered unique opportunities to develop, test and implement innovative technologies aimed at delivering sustainable human settlements and improving the performance of the house. Arising out of the Evaluation Reports, the CSIR was contracted by DST in January 2008 to "develop, test and implement innovative technologies aimed at improving the performance of the houses and contributing toward sustainable human settlements."

The houses were intended to be built in accordance with a low-income house plan as approved by the National Home Builders Registration Council (NHBRC). This is a 40 square meter housing unit comprising two bedrooms, a living area including a kitchenette, and a bathroom having a shower, a basin and a water closet (wc). The house is to be constructed of 140mm wide hollow concrete blocks on conventional concrete foundations, a conventional 75mm concrete floor slab on a damp proof course on compacted fill, steel window frames, steel door frames with timber doors internally and externally, and a roof assembly consisting of timber beams with a cranked steel roof sheet. Provision was to be made for cold water supply only, and for a single electrical board comprising a light and two plug points. No ceilings, roof or wall insulation, plaster, or rain water goods were provided. Both projects are located on hilly terrain, with slopes ranging from gentle to steep. Both projects were to be provided with roads (unpaved in the case of Mdantsane), and bulk water, storm water and sewerage reticulation. The Kleinmond project was to include street lighting and tarred roads (chip and spray). Due to the findings of the Environmental Impact Assessment, the number of houses in the Kleinmond project was reduced to 411 units.

Research methodology

The research methodology was based on two limitations, namely that all technologies would need to comply with the requirements of the National Building Regulations and Standards Act (Act 103 of 1977), and that the CSIR would test any innovative technologies prior to recommending such technologies for implementation.

Having regard for the above, the CSIR proposed to:

1) Investigate the identified technology requirements for each technology and best practice within the context of the projects including the applicable statutory and policy confines.
2) Determine the availability and suitability of each identified technology and best practice requirement having regard for the potential impact of each technology.
3) Perform a financial evaluation of each identified technology and best practice requirement.
4) Prepare and submit to DST a list of recommended technologies and best practices.
5) Upon instruction from DST, prepare Technical Specifications for each approved technology and best practice requirement for inclusion into the Contract of Works to be entered into by the relevant municipality.
6) Monitor the implementation of the approved technologies and best practices for compliance with the Technical Specifications.
7) Monitor the performance of the approved technologies and best practices for a minimum period of 12 months.
8) Evaluate the performance of the approved technologies and best practices at the completion of the monitoring period and compile an Evaluation Report for submission to DST

Development of Innovative Technologies

The building technologies and materials typically used in subsidized housing offer minimum performance standards with regard to the ingress and egress of heat and cold and moisture. The delivery of 2.2 million units however creates sufficient critical mass to warrant the investigation of the mass production of housing components in a manner that also creates jobs and upskilling for the local community. Since most of the units conform to one house plan, it is possible to prefabricate whole components, such as the roof, the plumbing installation, the wiring installation, and the bathrooms. Accordingly the CSIR developed and tested an alternative house design using innovative technologies to improve the performance of the house through the construction of three houses on its innovation site on the Pretoria Campus:

- House One was constructed according to the typical low-income house building plans as approved by the NHBRC;
- House Two was built according to the same layout but with building technologies typically used in suburban housing; and
- House Three was built based on the findings of the Technology Scan, the outcomes of the analysis derived from the construction of the first two houses; the examination and determination of construction best practice; and design proposals aimed at improving the performance of the house (van Wyk, de Villiers, and Kolev 2009).

The innovative technology process was aligned with the construction processes for easy reference, *i.e., sub-structure, super-structure, roof, finishes, and services* (Llewellyn-Davies & Petty: 1960; Barry: 1974; and Emmitt & Gorse, 2005).

Observations carried out on the construction of House One and House One and House Two revealed a number of areas where improvements were either required or were desirable. The plan layout of the NHBRC house is such that any extension of the unit requires substantial demolition of the existing structure. There are two causes of this: the first is that the roof sheets slope down toward the area of the site typically available for extension, limiting the vertical height of the extension and thus its horizontal dimension. To overcome this requires the removal of the entire roof sheet as the roof consists of one sheet cranked over the entire floor plan. The second cause has to do with the location of the services (bathroom and kitchen) as well as the window of bedroom three on the back wall of the house, requiring either the loss of a bedroom or the demolition of the kitchen and/or the bathroom – the most expensive components of the house – if horizontal expansion is to occur. Given that the subsidised house is meant to be a starter house, the inability to expand the house economically is a serious deficiency and is highly detrimental to the beneficiary.

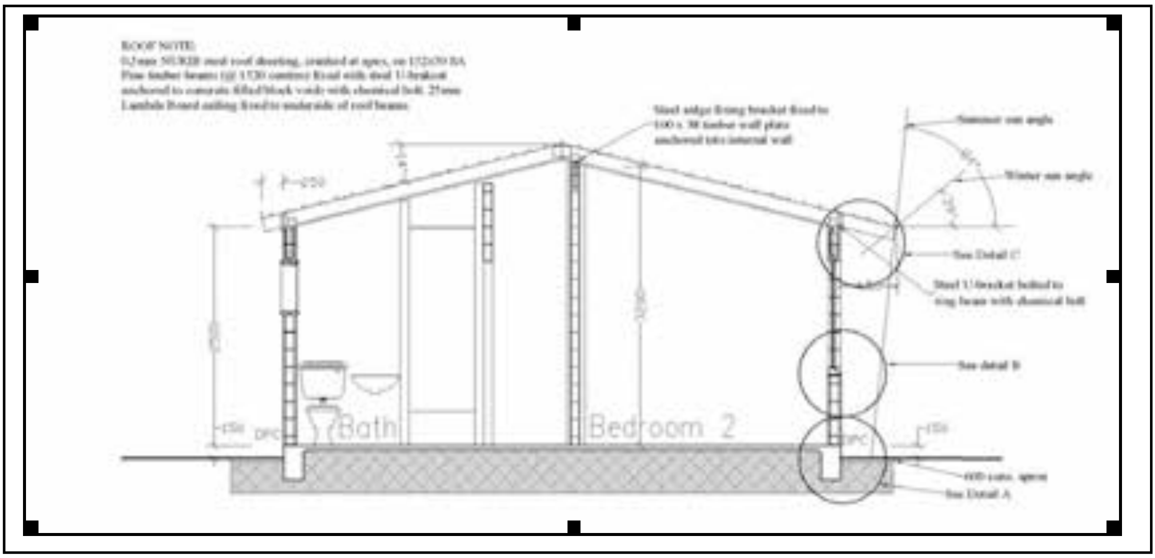

Figure 1: Section through house parallel to roof purlins/beams

House Three (see Figure 1) is thus designed so that no services are located on that part of the house to be extended, that no windows are placed in that part, and the roof slope is orientated in a manner that enables the ridge to be extended without the removal of any roof sheets. In addition, the rear door of the house is placed in the wall to be extended so that the beneficiaries can construct the addition and simply open up the door to access the extended house.

Problems typically arising out of the sub-structure construction relate to inadequate depth of excavations, inadequate backfilling, using inappropriately sized rubble for the backfilling, and inadequate structural strength of the foundation wall. As the CSIR has successfully developed, tested and implemented a thin concrete technology for roads, this technology was adapted for use on House 3. The technology for continuously reinforced concrete pavement (CRCP) comprises the use of a compacted base course treated with a diluted bitumen emulsion topped with a 193 steel mesh reinforced 50 mm concrete layer. The advantage of this technology is that it removes the need for excavations, concrete footings, foundation walls, backfilling, compacted sand layer and dpc and construction can be done using local labour and materials. For mass housing contracts it has the added advantage of facilitating the creation of a continuous platform, similar to road construction, requiring only the individual slabs of the houses to be excavated and cast. The platform is prepared 1m wider on each side, resulting in a hard stable external surface that also reduces mud splashing onto the lower courses when it rains.

Construction of the super-structure reveals typical severe shortcomings with regard to the control of the thickness of the mortar joints, and the cutting and wastage of a large number of blocks. This wastage was a result of a lack of co-ordination between the dimensions of the structure and the dimensions of the block, and the lack of joint thickness control during construction. With this in mind, House 3 was redesigned along modular lines, where the dimensions of the house are determined by the module of the hollow concrete block. Strict joint control and careful planning of the room dimensions resulted in a zero-waste circumstance requiring no cutting of blocks.

Construction of the roof assembly typically results in severe vibration at the junction between the wall and the roof sheet causing a horizontal crack in the top masonry course; and the thermal performance of the roof is extremely poor as a result of a lack of roof insulation. For House 3 two courses of U-shaped hollow concrete blocks are used below wall plate level: these are reinforced with a steel reinforcing bar and filled with concrete resulting in a continuously reinforced ring beam around the full perimeter of the house. The wall plates are laid on a screed laid to fall from front to back and secured to this reinforced beam by hoop iron fixed to the reinforcing bar and cast in. The fall enhances the discharge of rain water to water harvesting points at the corners of the building. The roof beams are orientated in a manner that results in the roof sheets running longitudinally rather than vertically: this enables the roof overhang to be structurally supported while making the whole roof act as a gutter. Tests on the site have confirmed that the overhangs protect the wall surface from rain, thereby minimising moisture penetration, and the rain water discharges at the corners.

Very little scope exists for improving or enhancing the finishes: given the financial constraints placed on low cost houses, the decision was taken to focus on improving the performance of the structure rather than on the cosmetic appearance of the house. However, as the housing location qualifies for the ‘coastal allowance’, an external plaster coat of ‘Perlite’ is applied which promises improved thermal and water resistance.

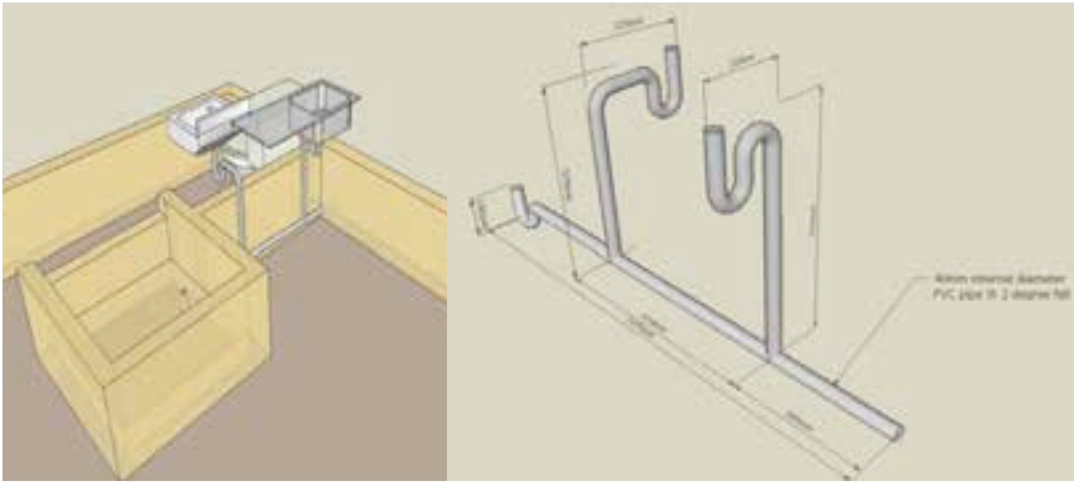

Figure 2: 3D view of plumbing manifold

With regard to services significant attention was paid to prefabricating the plumbing installation: to this end, a plumbing 'manifold' was developed that picks up the plumbing fittings and could be inserted into prepared penetrations through the block (see Figure 2). The result is a significantly shortened plumbing installation, and critically, since most of the installation is fixed internally, the potential for damage or vandalism is reduced.

With regard to environmental efficiency, the measures implemented in House One and House Two to improve the water and thermal efficiency were also applied. Specific NBR requirements for lighting and ventilation to the rooms, being 5 per cent of the room area for ventilation, and 10 per cent of the room area for light, are exceeded by the provision of an additional window in bedroom one and two additional windows to the kitchen area. With regard to water, the requirements for water-efficient taps, shower-heads, and dual-flush cisterns apply. With regard to thermal efficiency, an insulated ceiling board is installed. To minimise thermal bridging at the windows, use was made of precast concrete window frames for four of the seven windows. Provision was made for the installation of two rain water tanks at the rear of the building, and the roof was sloped from front to rear so that the entire roof acts as a gutter. Evaluation done in rainy conditions demonstrated that the rain water was indeed flowing to the rear corners as predicted.

Findings

Two modeling studies were undertaken post-construction of the test houses to determine whether the application of SET did result in measurable performance improvements.

The first study used computational modeling of each of the houses described in Section 4 and ran analyses to determine their thermal properties and to assess how they behaved in respect to daily and seasonal changes (Osburn 2010). The houses were constructed computationally using Energy Plus in accordance with the technical specifications of each house. A purchased air analysis was used to calculate the energy required to maintain a comfortable indoor environment.

In addition, simulations were run without a purchased air analysis for the hottest and coldest day for house 1 and the daily internal temperature of house 1 and house 3 were compared.

The second study undertook a Life Cycle Analysis (LCA) to assess the environmental performance of the default subsidy house (House 1) and the CSIR experimental house (House 3) to determine whether the application of SET delivered any measurable environmental performance improvements (Naalamkai Ampofo-Anti 2010). The LCA software tool, SimaPro 7.1, served as the main source of the life cycle inventory (LCI) data used in the study. The datasets applied in the study included transport services, energy services, and building materials with a view to assessing climate change impacts, energy consumption, material depletion, and water consumption.

With regard to the first, the study found that House 3 (the CSIR experimental design) required 56,2% less energy than House 1 (the default subsidy house) to maintain a comfortable indoor temperature.

Table 1: Comparison of Total Load between House 1 and House 3

House	Heating Load (GJ)	Cooling Load (GJ)	Total Load (GJ)
House 1	12.29	7.50	19.78
House 2	8.66	0.00	8.66

In order to assess other interventions that could be made to improve thermal performance it was modeled with carpeting, additional roof insulation, and wall insulation. The study found that the addition of a carpet further reduced the energy required by 73,0%; the addition of carpeting and 150 mm thick polystyrene roof insulation provided a reduction of 76,0%; while the addition of carpeting, 150 mm thick polystyrene roof insulation and 50 mm thick polystyrene wall insulation provided a reduction of 85,4%.

Table 2: Impact of Additional Insulative Materials on House 1

House	Heating Load (GJ)	Cooling Load (GJ)	Total Load (GJ)
Carpet	4.77	0.55	5.33
Plus roof insulation	4.54	0.20	4.74
Plus wall insulation	2.85	0.02	2.87

With regard to the second, the study found that House 3 requires about 35% less material resource input by weight compared to House 1 largely due to the replacement of conventional foundations with the thin concrete floor, the replacement of solid concrete blocks with hollow concrete block, and the elimination of floor screed. The study found that House 3 contributes less to climate change than House 1, the potential difference between the two designs being 685kg CO2 equivalents excluding operational reductions due to lower heating loads. The study further found that House 3 contributes less to water depletion than House 1. In additions to the two studies, simple calculations were done to determine the net energy and water savings that would accrue at a national scale if the technology was scaled-up. Assuming that the current backlog of 2.1 million units were constructed using this technology, the following reductions would accrue.

Table 3: National Resource Reductions

Innovative technology	Per House	National
Energy reduction heating/cooling	11,12 GJ	23 352 000 GJ
CO^2 reduction from materials	0,685 ton	1 438 500 ton
Material mass reduction	18,8 ton	39 480 000 ton
Water from materials	19,73 m3	41 433 000m3
Water, through rain water harvesting	22m3	46 200 000m3
Electricity savings SWH	1762.95kWh/annum	3.7 billion kWh/annum
Electricity saved PVP	36kWh/annum	75.6 million kWh/annum
CO^2 reduction SWH	2.11 ton/kWh/annum	4.4 million ton/annum
CO^2 reduction PVP	0.04 ton/kWh/annum	90 300 ton/annum

Conclusion

The study finds that there is substantial scope for innovative technology to improve the performance of low-cost housing in South Africa. However, the study also finds that a significant impediment to performance improvement in low-cost housing is the difficulty that small contractors have in assimilating innovative technology, especially having regard to the poor construction practices demonstrated in low-cost housing projects.

Innovative technology can be applied to substantially improve both the Indoor Environmental Quality (IEQ) and general performance of low-cost housing in South Africa, thereby improving the quality of life of the beneficiaries. Innovative technology can also reduce the amount of material used, and the amount of waste produced during construction.

The limitations include limited funding to cover the extra costs arising out of the implementation of innovative technologies, delays caused to the performance measurements as a consequence of inclement weather experienced during the construction period as well as difficulties in establishing a sufficiently robust IEQ performance measurement protocol.

Modular co-ordination was affectively applied in House 3 demonstrating better quality block-work by the same team that had built House 1. The stringency of maintaining the 10mm joint to ensure the fitting of doors and windows and building by the block rather than a conceptual dimension meant no breakage or cutting and hence no waste. It also meant no mistakes, except where insufficient documentation was provided. Where cutting did occur it was such that both portions of the block were used. Modular co-ordination has to be broad based to be effective and the variety of units kept to a minimum. All units needed for designed co-ordination must be available to the user.

With too many units to make it workable the various manufacturers across the country only produced those units found to be more popular in their region, once again fuelling the need for cutting and breaking on site.

The altered design of the standard house for growth and development over time as demonstrated meets a strategic goal for this study in that it provides a home base model for achieving sustainable human settlements over time that was not feasible with the previous standard house. As the research progresses it has yet to demonstrate how the model can go to scale in all senses: concept, technology, financing, implementation, monitoring, and evaluation which are all aspects of the study.
The general approach of the research is holistic in that all aspects of research are seen within a dynamic sustainable urban model that supports a broad-based and common set of goals and objectives: house design, performance, a healthy working and living environment and opportunity for economic activity and sustainable livelihoods.

The technologies being researched are simple applications of available materials and methods but in such a way as to add sustainable value to the property and its users at little additional cost.

The objectives are, in short the following: more comfortable buildings that perform better, are durable, quick to build, readily alterable, easily extendable, and less dependent on municipal services. While the necessary research framework and the building structures are complete or nearing completion for testing the research questions 1 and 2, as regards the standard subsidy house and the suburban version, remain unanswered as to performance at this stage. Sub questions 3 and 4 as regarding good and best practice have been dealt with in the research as necessary components of the process of the research, informing the technology selection and development for House 3. Sub-questions 5, 6, await the availability of all three houses for processing time, cost and manpower data as well as the testing of performance of all three houses and processing the results. This latter work should be enabled on completion of House 3 by end April 2009. Sub-question 7 regarding roll-out of housing incorporating final recommendations will follow both during the remaining research period and on completion of final results and consideration of their implications in the low-cost housing environment. The project remains on target as regards its original research focus.

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