Conceptualising a sustainable energy solution for in situ informal settlement upgrading

by

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Declaration

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Abstract

South Africa's *Upgrading of Informal Settlements Programme* (actuated through the *Breaking New Ground* policy directive) and pro-poor energy policies continue to contribute towards the spatial and economic marginalisation of slum dwellers, in spite of sharing the mutual objectives of poverty alleviation and the promotion of equality. The intersecting nodes of the human settlements and energy policy mechanisms result in the continuation and deepening of energy poverty at the poor urban household level.

The human settlements policy terrain is still characterised by the glaring absence of a mainstream approach that actively engages with informality, despite the dawning realisation of the permanency of informality in national policymaking spheres. A stylised energy-shelter development trajectory, composed of current human settlement and energy policy sanctioned response mechanisms, reveal an 'All-or-Nothing' policy approach to shelter and energy infrastructure provision at the informal household level.

Through a Transdisciplinary Research approach, this work attempts to design additional and intermediary developmental responses along the stylised energy-shelter trajectory which simultaneously have the ability to address household energy poverty. Proposed interventions involve the retrofitting of an existing shack through ecological design features and insulation; as well as the construction of an improved shack (iShack) along ecological design principles with the introduction of an incrementally scalable solar photovoltaic DC Multigrid System. These incremental development responses were piloted in situ in the informal settlement of Enkanini (Stellenbosch). A statistical analysis of the retrofitted shack and iShack Indoor and Outdoor Temperature measurements, benchmarked against a control shack, reveal daily thermal comfort increases of 3h34m and 4h45m respectively.

A re-examination of the current human settlements and energy policy terrain is conducted to reveal the spaces where the additional and intermediary energy-shelter development responses could be supported. Sustainable energy interventions are possible under the Free Basic Alternative Energy subsidy, whilst the Emergency Housing Programme offers the possibility of energy poverty alleviating shelter interventions, however not proactively and at scale.

A case study of the Baan Mankong programme (the Thai equivalent of the *Upgrading of Informal Settlements Programme*) is used to extract a set of key principles and lessons in order to inform a necessary human settlements policy iteration towards one that could enable incremental and intermediary energy poverty alleviating shelter transitions.

Opsomming

Suid-Afrika se program vir die opknapping van informele nedersettings ("Upgrading of Informal Settlements Programme", oftewel UISP), wat deur middel van die "Breaking New Ground"-beleidsdirektief in werking gestel is, en armgesinde energiebeleid dra steeds tot die ruimtelike en ekonomiese marginalisasie van krotbuurtbewoners by, ondanks die gemeenskaplike oogmerke van armoedeverligting en die bevordering van gelykheid. Die oorvleuelende nodusse van die beleidsmeganismes vir menslike nedersettings en energie lei tot die voortsetting en verergering van energiearmoede in arm stedelike huishoudings.

Ten spyte daarvan dat die permanensie van informaliteit al hoe duideliker tot nasionale beleidvormers deurdring, word die beleidsomgewing vir menslike nedersettings steeds gekenmerk deur ’n opvallende gebrek aan ’n hoofstroombenadering wat daadwerklik daarmee erns maak. ’n Gestileerde energie-behuising-ontwikkelingsbaan, wat uit reaksiemeganismes ingevolge heersende menslike-nedersettings- en energiebeleid saamgestel is, dui op ’n ‘alles of niks’-beleidsbenadering tot behuising- en energie-infrastruktuurvoorsiening op informele huishoudelike vlak.

Deur ’n kruisdissiplinêre navorsingsbenadering probeer hierdie studie bykomende en intermediêre ontwikkelingsreaksies op die gestileerde energie-behuising-baan ontwerp, wat terselfdertyd huishoudelike energiearmoede kan verlig. Voorgestelde intervensies behels die retro-aanpassing van bestaande plakkershuise deur die installering van ekologiese ontwerpkenmerke en isolasie, sowel as die konstruksie van ’n verbeterde informele woning (die iShack) volgens ekologiese ontwerpbeginsels deur die inwerkingstelling van ’n trapsgewys skaleerbare fotovoltaïese gelykstroom-veelnetwerkstelsel. Hierdie inkrementele ontwikkelingsreaksies is ter plaatse in die informele nedersetting Enkanini (Stellenbosch) op die proef gestel. ’n Statistiese ontleding van die retro-aangepaste plakkershuis en binnenshuise en buitenshuise iShack-temperatuurmetings, met ’n kontrolehuis as rigpunt, dui op daaglikse toenames in termiese gemak van 3 h 34 m en 4 h 45 m onderskeidelik.

’n Hersiening van die huidige beleidsomgewing vir menslike nedersettings en energie word onderneem om te bepaal waar die bykomende en intermediêre energie-behuising-ontwikkelingsreaksies ondersteun sou kon word. Die subsidie vir gratis basiese alternatiewe energie bied ruimte vir volhoubare energie-intervensies, terwyl die noodbehuisingsprogram die moontlikheid inhou van behuisingsintervensies wat terselfdertyd energiearmoede verlig, hoewel nie proaktief en op die vereiste skaal nie.

’n Gevallestudie van die Baan Mankong-program (die Thaise ekwivalent van die UISP) word gebruik om ’n stel hoofbeginsels en -lesse te bepaal waarvolgens die beleidsbenadering tot menslike nedersettings aangepas sou kon word om ’n oorgang te bewerkstellig na inkrementele en intermediêre behuisingsontwikkeling wat terselfdertyd energiearmoede verlig.

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Acronyms

BNG – Breaking New Ground
CODI – Community Organisations Development Institute
COGTA – Department of Cooperative Governance and Traditional Affairs
CORC – Community Organisation Resource Center
CSIR – Council for Scientific and Industrial Research
CPI – Consumer Price Index
DAG – Development Action Group
EFA - Electricity-for-All
EHP – Emergency Housing Programme
ERC – Energy Research Center
ESMAP – Energy Sector Management Assistance Programme
EEU – Environmental Evaluation Unit
FBE – Free Basic Electricity
FBAE – Free Basic Alternative Energy
IDA – Incremental Development Area
ISUG – Informal Settlement Upgrading Group
kWh – Kilo Watt-hour
LPG – Liquid Petroleum Gas
MINMEC – Minister and 9 Members of the Executive
NBR – National Building Regulations
NEP – National Electrification Programme
NHBRC – National Home Builders Registration Council
NUSP – National Upgrading Support Programme
NRF – National Research Foundation
SABS – South African Bureau of Standards
SDI – Shack/Slum Dwellers International
SI – Sustainability Institute
SSS – Specialized Solar Systems (Pty) Ltd.
TA – Technology Assessment
TD – Transdisciplinar(it)y
TnDBT – Dry Bulb Neutrality Temperature
TRA – Temporary Relocation Area
TSAMAHub – Transdisciplinary Sustainability Analysis, Modelling and Assessment Hub
UCT – University of Cape Town
UISP – Upgrading of Informal Settlements Programme
Wh – Watt-hour
WHO – World Health Organisation

Chapter One: Introduction

1.1 Background to this study

In order to promote cutting edge research towards addressing South Africa's and Africa's most pressing challenges, Stellenbosch University initiated the HOPE Project in 2010 with the aim of creating sustainable solutions through teaching, learning, research and community interaction (University of Stellenbosch, n.d.). Under the HOPE Project banner, an institutional structure in the form of the TsamaHUB (Transdisciplinary Sustainability Analysis, Modeling and Assessment Hub) was established to promote transdisciplinary studies in order to grapple with those problems that are too complex for single disciplines to solve (TsamaHUB, n.d.).

The TsamaHUB was awarded funding in 2011 by the National Research Foundation's (NRF) Community Engagement Programme for a 3-year period in order to conduct research into Sustainable Community Transitions. More specifically, the funding was awarded with a view at generating knowledge that is necessary to enable sustainable in situ upgrading of informal settlements. A radical shift in the approach to Human Settlements in 2004 now mandates local governments to create sustainable human settlements through, amongst other aspects, the in situ upgrading of informal settlements under their jurisdiction. This shift was promulgated through the introduction of the *Breaking New Ground: A Comprehensive Plan for the Development of Sustainable Human Settlements* (BNG) policy which sought to address many of the shortcomings of the original RDP housing policy[1] and paved the way for the formation of the Upgrading of Informal Settlements Programme (UISP). In situ upgrading however, as envisaged by the UISP, has not been implemented, in spite of clear elucidation in the policy, a newly established funding mechanism and the creation of a dedicated support institution – the National Upgrading Support Programme (NUSP). The reasons for the non-adoption of the policy are explored in depth in this research, but suffice to say at this stage, that one of the primary reasons for the non-adoption of the policy is the lack of clear examples of in situ upgrading pilot projects. The NRF funding thus enabled the formation of the Informal Settlement Upgrading Group (ISUG), a transdisciplinary group of researchers and affiliate institutions tasked with piloting sustainable ways in which to realise in situ upgrading in a real life context, that is, the informal settlement of Enkanini (see Appendix A for background on Enkanini).

Conscious of a common pitfall of applied research which fails to disseminate research results and bring direct benefits to the subjects of their enquiry – it is envisaged that the ISUG becomes a long term innovation hub into developmental responses to informality, with successive researchers building on the research of their predecessors. Thus the continued interaction between researchers and community members is ensured, and the research findings are not only implemented, but continuously improved. Initiating the ISUG in 2011 was Lauren Tavener-Smith, a Phd student and economist focusing on water and sanitation; Joel Bronkowski, an Mphil student and social scientist focusing on community mobilisation and enumeration strategies; Lweendo Hamukoma, a BPhil

[1] A colloquial term describing low-cost housing settlements, initially operationalised under the ANC's Reconstruction and Development Plan (RDP), its first socio-economic roadmap after the democratic transition and characterised by greenfield developments of sterile, uniform built environments on the urban periphery.

student with a policy background investigating community perceptions to urbanisation and informality; and the researcher, an MPhil student with a finance background assessing the viability of improved dwelling constructions and energy infrastructure systems. In 2012, the ISUG was joined by Vanessa von der Heyde, an MPhil student with Marketing background focusing on waste management in Enkanini; as well as Berry Wessels, a social anthropologist, who is building on this research through the exploration of institutional, financial and governance structures necessary to bring grassroots, people-driven energy interventions to fruition. The ISUG meets at least once a week to further internal discussions, plan and co-ordinate community activities and discuss ongoing research.

Whilst vested in the TsamaHUB, the ISUG formed strategic partnerships with numerous organisations, all sharing a common interest in in situ upgrading. Firstly, Stellenbosch Municipality – a progressive local government in the sense that it is the second municipality in South Africa to create a separate Informal Settlement Unit, with dedicated resources, to address the development opportunities of slums within its jurisdiction. It is one of the few municipalities currently attempting to upgrade in line with the UISP. Secondly, Slum/Shack Dwellers International (SDI), an umbrella body of grassroot community organisations with a substantial footprint in many of Cape Town's informal settlements. SDI and its international affiliates have significant experience in mobilising communities to initiate people-centered development by the poor themselves. Thirdly, the Sustainability Institute (SI), the academic base of the Transdisciplinary Phd, MPhil and BPhil students, as well as the operational base for the ISUG, where it gathers for meetings, discussion and planning activities. The SI furthermore provides valuable resources and experience in training, supporting and working with disempowered community members.

1.2 Motivation for this study

Prior to studying towards the BPhil in Sustainable Development (the prerequisite to the MPhil in Sustainable Development), the researcher had completed a Bachelor of Business Science (Finance and Accounting) at the University of Cape Town and had worked as a Hedge Fund Administrator in Cape Town. During the BPhil coursework, the researcher took a course on Renewable Energy Financing, where an open brief was provided for the topic of the post-course assignment. The researcher chose to look at the Energy Poverty Nexus – how poverty influences the fuel choices of poor people and conversely how the fuel choices of poor people can have poverty entrenching dynamics. It was discovered that energy was a 'low-hanging fruit' in challenging poverty and that the core barrier to clean fuel transitions for poor households was often a financing issue. Access to, and the continued affordability of clean energy sources could be assisted through carefully designed financial interventions that had wide ranging poverty alleviating effects. This newfound understanding led the researcher to investigate pro-poor finance and market mechanisms geared towards the Bottom of the Pyramid by reading case studies and reports from development agencies and practitioners that spoke about the failures and success of pro-poor energy projects.

The researcher participated in a 3-week course on Social Entrepreneurship in Colombia in December 2010 in an attempt to further his understanding of market-based development opportunities that placed communities into the centre of development processes. The researcher was interested to learn how these might be adapted to clean energy transitions at scale. He found that the correct contextualised mix of finance, governing institutions and processes can allow autonomous grassroots initiatives to deliver both social and economic returns.

During preliminary research proposal discussions with Professor Mark Swilling, it was suggested that these focuses be combined within the context of informal settlement upgrading, and for the researcher to join the ISUG.

1.3 Refining the Research Topic

The process of developing a research topic took approximately 7 months (January – July 2011) for numerous reasons. Firstly, the attempt at tying together the conceptual strains of in situ informal settlement upgrading and energy infrastructure, which were examined through the prism of the energy poverty nexus, proved to be challenging since this required an intimate understanding of the technical, procedural, legislative and practical approaches and challenges which accompanied the role of energy infrastructure during upgrading. Secondly, few upgrades had been conducted under the programmatic auspices of the UISP resulting in a lack of practical case studies which could inform the researcher's own understanding of the complexities involved in this new approach to addressing informality. Thirdly, the researchers own grasp on what the *real* issues were in regards to energy poverty and upgrading was continually changing as a result of countless discussions, site visits etc. that the ISUG was exposed to in formalising working arrangements with its research partners. Lastly, the research was commencing in a politically sensitive time with the approaching May 2011 local government elections. The ISUG had been instructed by Stellenbosch Municipality to avoid research activities in Enkanini (the focus of its field work) until after the elections, for fear of having any research activities politicised. The role and identity of the researchers, which was crucial in determining prior to any community engagements (which in turn, was necessary for the researcher's topic development stage), was subject to weeks of deliberations, brainstorming and work shopping. This allowed more time to deepen the literature search and to have more informative conversations. The delays in moving beyond the research topic development phase are also the reason for the two-year timeframe of this study.

The first research proposal was informed by a desktop study of the human settlements and pro-poor energy policies, academic literature on the energy poverty nexus and energy transitions theory as well as research reports outlining poor-friendly market options which were demonstrated through case studies. Within the context of informal settlement upgrading, the preliminary investigation revealed that there was a need to reconceptualise the manner in which informal settlements were energised, since the business-as-usual approach was unsustainable and increased energy poverty levels of poor households. Given that access cost and continued affordability were the primary hurdles precluding clean energy access for poor people, the researcher intended to look at new and existing financial flows within informal settlements which could be modified to enable incremental sustainable energy infrastructure investments, with the understanding that these could have a beneficial effect on the energy poverty level of poor households. The primary research objective was thus to investigate an alternative, more sustainable financial and technical model in which in situ informal settlement energisation could be affected with associated household energy poverty alleviation dynamics.

The researcher concerned himself with the technical delivery model first. An interview with Ewald Biesenbach (electrical engineer at the engineering consultancy Aurecon) revealed the near impossibility of energy infrastructure innovations towards sustainable systems at the informal settlement level. This was due to a set of heavily prescribed engineering norms and standards enforced through tender processes, and the industry practice of 'copy-and-pasting' prior designs for new projects, i.e. there was no pay-off for innovation – it was grid electricity or no energy. This perception was confirmed by Nombulelo Zwane (Stellenbosch Municipality electrical engineer) who added that Engineering Council of South Africa accreditation enforced adherence to standards and protocols and furthermore, that there was no need for innovations since the current standards were functional and ensured the safety of users. Two interviews with Dawie Carolissen (Stellenbosch Municipality director of informal settlements) painted a similar unpromising picture on the housing front. Municipal officials were forced to do depth interventions, that is, build houses in accordance to exceptionally high norms and standards, instead of breadth interventions which may have spread poverty alleviating benefits further. This approach was imposed by policy prescriptions which are enforced through contingent funding releases.

Following these interviews, the researcher realised that without a relaxation or adaptation of the exceptionally high norms and standards and prescribed processes, little scope for technical innovation towards an alternative energy poverty alleviating system was possible. In the words of Professor Swilling, "currently quality assurance is married to a given technical delivery system" (Keller, 2012). Subsequently, for a brief period, the researcher endeavoured to interrogate the orthodoxy of the energy technical system as it related to policy, tenure procedures and technical norms and standards. This involved shifting the focus onto reconceptualising a more sustainable energy and shelter result by attempting to identify the decision-making nodes where energy infrastructure and human settlement development intersected. To understand the technical dimension as it related to electricity distribution infrastructure and systems, the researcher conducted numerous literature searches at the Stellenbosch Engineering Library but soon realised that investigations into technical innovations optimised on cost, safety and operations and maintenance requirements, would have been beyond the scope of this study and was dependent on an engineering background. The researcher had reached a cul-de-sac in an ambitious attempt to unpick the constricting tenets of the current technical delivery system and realised that it would be more beneficial to proactively design and conceptualise alternatives as opposed to merely interrogating the existing approaches through a reductionist focus on technology and norms and standards.

Fortunately, a case study of the Orangee Pilot Project (Karachi, Pakistan), where community-constructed incrementally improved drainage and sanitation systems a) catalysed shelter upgrades which were subsequently b) connected to formalised city engineering services, provided the researcher with fresh insights with which to approach the research topic. This discovery coincided with a research exchange to the Sheffield Road and Joe Slovo informal settlements where shelter upgrades and the release of public space had been achieved through shelter re-blocking activities; and the City of Cape Town had subsequently installed toilets into the recouped space. The researcher was curious whether similar results could be achieved through energy infrastructure upgrades – for upgrades to be integratable into formalised energy systems and for the upgrading momentum to catalyse informal dwelling improvements. The former notion was important since in order to encourage energy infrastructure investment by poor people, their future obsolescence or redundancy had to be avoided. Perhaps shelter upgrading and energy infrastructure upgrading could simultaneously and complementarily be achieved?

In order to determine this, the researcher populated a list of potential shelter development stages where poor people (including informal settlers) could be. Through the information gathered by that time, it was possible to map the possible energy and shelter trajectories which were attainable from these stages, i.e. the business-as-usual approach. The next challenge was to conceptualise what these selfsame energy-shelter trajectories could look like if conducted more sustainably. This led the researcher to disaggregate shelter from energy – to look at each aspect independently – and then to combine them again into a sustainable energy shelter trajectory.

On the shelter front, the researcher visited conventional (Thobelitsha, Stellenbosch) and more sustainably (Witsand, Atlantis) constructed low-cost housing settlements to get a comparative understanding of the potential for energy-mindful shelter construction. Besides the re-blocking exercises actuated under the SDI auspices, the researcher could not find any shelter improvement initiatives at the informal shack level. This struck the researcher as peculiar, given the predominant consensus in the literature that informality had already become a legitimate urban form and, given increasing urban inmigrations and resource constraints, was a phenomenon that was here to stay. Why not engage with informality and improve what is here already? These realisations were confirmed during an interview with Mark Misselhorn (CEO of Project Preparation Trust, Durban) where he noted that no policy sanctioned top structure response was currently available at the level of the shack and that interim measures were confined to engineering services.

Professor Swilling encouraged the researcher to explore the notion of sustainable informal shelter responses further, since there appeared to be a significant gap within policy, academic research and practice. Additional investigations revealed that discrete aspects of informal shelter research had been conducted, such as an extensive study into shack insulation materials by the Energy and Environment Unit at UCT; and research into fire resistant materials by the People's Environment Planning NGO. The researcher began to explore the concept of additional and intermediary dwelling interventions along the energy shelter trajectory that had previously been conceptualised, by attempting to add additional stages along the trajectory, and in so doing increasing the opportunity set for incremental shelter improvements prior to formalisation (which in any case will elude most slum dwellers in their lifetimes). The indoor measurement and verification results of the Witsand IEEECO™ low cost houses revealed that significant energy-in-use savings (and emission reductions) could be achieved through ecologically sound construction. The researcher endeavoured to find ways in which these similar benefits could be achieved at an informal level and to investigate whether these may have direct energy poverty alleviating effects.

There was a concern that by solely focusing on energy-mindful informal shelter improvements, that the energy infrastructure component would be sidelined. For this reason, the researcher engaged in numerous discussions with energy consultants and researchers[2] to be on par with the current state of sustainable energy technologies with the idea of finding a suitable technology that a) had inherent energy poverty alleviating potential and b) could be interwoven into the shelter stages that were being identified.

The researcher came across an innovative new solar system that had recently been designed by Specialized Solar Systems (Pty) Ltd. (SSS) which was built according the Direct Current (DC) principles. Through the elimination of DC-AC conversion, these systems consumed DC electricity directly in DC appliances, allowing efficiencies to increase and costs to be reduced. SSS had developed a DC Multigrid system, consisting of a core unit which could incrementally and progressively have additional appliances added on over time. Furthermore, through the installation of a grid interface module, the entire system could seamlessly be integrated into the AC grid. A system had therefore been found which was perfectly suited to the intermediary and progressive dwelling developments that had conceptualised along the shelter trajectory.

After these research topic iterations, the researcher was satisfied that a significant gap in the current policy and practice in regards to informality and energy poverty interventions in South Africa had been identified. The researcher decided that additional and intermediary energy-shelter stages should be subject to a transdisciplinary design process through the combined efforts of experts and lay people alike, since TD research is particularly suitable to the problems under investigation. Furthermore, the researcher determined to test additional and intermediary energy-shelter stages in a real-life setting to get an impression of the intricacies involved in constructing these additional responses; and to gain user feedback on the usability and experience of interventions. In order to verify the efficacy of the interventions as energy poverty alleviators, a statistical analysis of the thermal performance and thermal comfort performance of the proposed interventions (based on measurements of Indoor and Outdoor temperatures) was to accompany the feedback of users. Finally and pragmatically, revising the human settlements and energy policy terrain was necessary to determine the spaces where these additional energy-shelter responses could be actuated; and failing so, an attempt should be made at deriving a set of principles that should underpin a policy iteration that could enable sustainable energy-shelter transitions in future.

[2] Frank Spencer (energy consultant at Emergent Energy); Riaan Meyer (research engineer at the Center for Renewable and Sustainable Energy Studies); Prof. Ben Sebitosi (Research Engineer at the Center for Renewable and Sustainable Energy Studies); Prof. Gisela Prasad (Energy Research Center at UCT); Dr. Beatrice Wiid (Interchange Foundation); Restio Energy (in Somerset West) and Specialized Solar Systems (in George).

1.4 Research Problem and Objectives

Given this understanding, the primary research problem of this work may be framed as follows:

What role can additional sustainable energy and shelter improvements play in alleviating energy poverty during in situ incremental upgrading of informal settlements?

In order to answer this problem statement, the following research objectives were identified:

1. Determine what the current South African policy and practice is in regards to in situ informal settlement upgrading and pro-poor energy improvements (*Systems knowledge*).

2. Investigate whether the current human settlements and energy policies affect energy poverty at the informal household level (*Systems knowledge*).

3. Explore alternative sustainable energy and in situ upgrading shelter improvement responses that may simultaneously be energy poverty alleviators (*Target knowledge*).

4. Identify spaces within the human settlements and energy policies that could support sustainable energy and shelter improvements (*Transformation knowledge*).

5. Derive a set of principles that should underlie an alternative notion of in situ incremental upgrading with regards to sustainable energy and shelter improvements (*Transformation knowledge*).

1.5 Key Concepts

DC Electricity – Direct Current (DC) electricity is the unidirectional flow of electrical charge that is generated by a solar photovoltaic cell. DC is inverted to Alternating Current (AC) in order to be consumed in standard household electrical appliances.

Ecological Design – “any form of design that minimizes environmentally destructive impacts by integrating itself with living processes” (Van der Ryn & Cowan, 1996:18) such as sunlight and shade, air movements, plants and the inherent thermal properties of certain natural materials.

Energy-in-use – energy requirements resulting from the use of a building which are directly affected by its design.

Energisation – “…the transitional process of progressively meeting [...] [the] energy service needs of a poor economic subgroup […] through the delivery of an enhanced quantity, quality and/or variety of accessible and affordable energy services…” (Nissing & Von Blottnitz, 2010:2186).

Energy Poverty – "The absence of sufficient choice in accessing adequate, affordable, reliable, quality, safe and environmentally benign energy sources to support economic and human development" (TERI, 2008:2).

Energy Services – Energy-enabled services that contribute towards human wellbeing, such as heating, cooking, lighting, water heating, entertainment, communication etc.

Incrementalism – The "belief in or advocacy of change by degrees; gradualism" (Oxford Dictionaries, n.d.). In the context of this work, incrementalism refers to progressive and additive steps in energy infrastructure and shelter development.

Informal Settlement – A human settlement "…characterized by inadequate housing conditions; deficient urban services (water supply, sanitation, drainage, solid waste disposal, and roads and footpaths); unsanitary and dehumanizing living conditions; extremely high densities (of both people and dwellings); and, frequently, long travel distances to job opportunities" (Majale, 2008:271).

Informal Settlement Upgrading **–** A contested notion that is explored in this study. For more governments and development practitioners, upgrading denotes actions that improve the physical environment of slum dwellers. An expanded understanding may extend to any activity that brings about a net improvement to the wellbeing of informal settlers through, *inter alia*, the building of capabilities.

Informal Settler – a resident of an informal settlement.

iShack – 'improved shack' and an additional incremental shelter response advocated in this work.

Retrofit – improvements introduced to an existing structure to enhance e.g. energy efficiency, thermal comfort. A Retrofit shack is an additional incremental shelter response that is advocated in this work.

Slum – a term used interchangeably with *Informal Settlement*.

Slum Dweller – a term used interchangeably with *Informal Settler*.

Transdisciplinarity – Research that transcends and integrates disciplinary paradigms; is participatory in nature; relates to life-word problems; and searches for unity of knowledge beyond disciplines (Pohl & Hirsch Hadorn, 2007).

Thermal Comfort – "A state in which there are no driving impulses to correct the environment by behaviour" (Djongyang et al., 2010:2627).

Renewable Energy – An energy source derived from renewable sources such as solar, wind, geo-thermal and ocean energy. These sources have reduced lifecycle greenhouse gas emissions compared to fossil fuels.

Modern or Clean Energy – Fuels such as Electricity and Liquid Petroleum Gas (LPG) which are more efficient and generate less emissions at the point of use in comparison to *Traditional Fuels*.

Sustainable Energy – An energy source which offers a net improvement in the social, environmental and economic situation of users. The concept goes beyond that of *Renewable Energy* which has an environmental bias.

Traditional or Primitive Fuels **–** Biomass, crop residues and animal dung. These fuels are the worst emitters and most expensive fuels per unit of useable energy due to their inherently low calorific values and utilisation in inefficient appliances.

1.6 Significance of the Study

South Africa has subscribed to the United Nation's Millennium Development Goals (MDG) which aim to improve the lives of 100 million slum dwellers by 2020 (Goal 7, Target 11). Access to clean energy sources however underpins all MDGs thus elevating the importance of promoting transitions to more modern fuel sources for all poor people (UN-Energy, 2005). Furthermore, 2012 is the International Year of Sustainable Energy For All, an initiative of the United Nations Secretary-General that seeks to enact universal access to modern energy sources by 2030 (UN-Energy, 2011).

South Africa's international commitments have informed its own policy approach. Both the Human Settlements and Energy policies share the mutual objectives of poverty alleviation and the promotion of equality (DME, 2001; DoH, 2004). More specifically, South Africa has a target of upgrading 400 000 households by 2014 (Zuma, 2011) as well as achieving universal access to electricity in the near future (the 2012 target has been extended indefinitely). This study would thus contribute towards both international as well as national targets and mandates of improving the lives of slum dwellers through shelter and energy infrastructure improvements.

South Africa is one of the world's most unjust societies. Informal settlements and all their societal afflictions live on our doorstep. From a purely humanistic perspective, we have a moral responsibility to help fellow human beings and contribute towards the creation of a fairer society. It is the researcher's belief that this study engenders the possibility of contributing to these ideals.

1.7 Research Approach

"The world has problems, but universities have departments" – (Brewer, 1999:328)

"*There is a need for TR [transdisciplinary research] when knowledge about a socially relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them*" – (Pohl & Hirsch Hadorn, 2007:20)

The research approach of the ISUG researchers is transdiciplinary[3] (TD) in nature as this is an appropriate and effective means in which to research complex societal problems, such as moving from informality to incremental in situ upgrading. "The contribution of research to the solution of these problems will not be answers to conceptual puzzles, but rather, practical outcomes that can be applied in a social or environmental context and which therefore bring about some degree of change in those contexts" (Wickson et al., 2006: 1049). This specific quote influenced the way in which the researcher went about designing this study – the intention was to render practical and applicable results.

1.7.1 Transdisciplinary research approach

The researcher followed the precepts outlined in *Principles for Designing Transdisciplinary Research* by Pohl and Hirsch Hadorn (2007) in designing this research study. The publication served as a guidebook as the researcher navigated through the various parts of this study and was particularly useful given the vast hermeneutic latitude that exists in regards to TD definitions and approaches. Fundamentally, TD research follows three phases, namely:

1. Problem identification and structuring
2. Problem analysis
3. Bringing results to fruition

These phases do not necessarily have to progress consecutively and indeed it is expected that iterations during the research process may require the revising of a prior step, e.g. problem analysis

[3] It may be useful to clarify the concept by contrasting it against alternative modes of knowledge production. Manfred Max-Neef, the Chilean Economist and TD pioneer grades the approaches along a continuum from Disciplinarity to Transdisciplinarity according the level of co-operation and integration of knowledge components. *Disciplinarity* involves the specialisation and subsequent fragmentation of faculties into 'knowledge silos' through their institutionalisation into isolated departments, e.g. Chemistry, Biology. *Multidisciplinarity* involves no cooperation and no coordination between a team of researchers which apply their field of expertise to a certain problem with the final result being an agglomeration of unintegrated perspectives. *Pluridisciplinarity* involves cooperation between disciplines without coordination and occurs at a horizontal knowledge hierarchy. It lends itself well to compatible areas of research which give rise to mutually reinforcing results, e.g. bio-physics. *Interdisciplinarity* involves the coordination and cooperation from an elevated hierarchical perspective of multiple disciplines. Lastly *Transdisciplinarity* implies coordination and cooperation between multiple hierarchical levels in pursuit of a shared problem (Max-Neef, 2005).

requires a revision of the problem identification. Furthermore, TD research needs to adhere to four requirements, which emerge during the problem analysis phase:

1. Come to terms with complexity
2. Take into account diversity
3. Develop case-specific and practice-orientated knowledge that can be transferred
4. Oriented towards what is perceived to be the common good.

The authors caution against trying to meet all requirements at the onset of a research process, for fear of overloading the project with prerequisites which can have a stifling effect. Instead, they offer a set of principles that should inform the research design and would inevitably lead to adherence to the requirements. The researcher thus allowed himself to be led by the following four TD principles in choosing the research methods (Pohl & Hirsch Hadorn, 2007).

1. Reduce complexity by specifying the need for knowledge and identifying those involved
Choosing only those aspects relevant to 'practice-orientated problem-solving' is important in reducing the complexity that accompanies a given research problem (Pohl & Hirsch Hadorn, 2007). Furthermore, it is useful to facet research in accordance to the following sets of knowledge, which TD research aims to generate:

> *System's knowledge* is knowledge about the current system or problem situation. This recognises that there may be uncertainties about the genesis of the problem, along with different interpretations depending on the goal of participants.
> *Target knowledge* is about the desired future status. This recognises the pluralism of norms and values that may be present, depending on actors' perceptions of the system, system relations and options for change.
> *Transformation knowledge* is about how to make the transition to the target status. This includes technical, social, legal, institutional and other changes (Hadorn et al., 2008:30-31) in Cronin (2008).

Complexity can be reduced further by identifying and assigning tasks to stakeholders and identifying a particular knowledge facet that the TD research is trying to generate (Pohl & Hirsch Hadorn, 2007). In this study however, the researcher shall attempt to generate systems, target and transformation knowledge in regards to the research problem and objectives, since the researcher found this to be an exciting challenge and since this was in line with his own instinctive and pragmatic approach to designing research.

2. Achieve effectiveness through contextualisation
TD concerns itself with an attempt at generating knowledge that addresses socially relevant problems in a concrete fashion. An assessment of the state of knowledge and societal practices in regards to the identified research objectives is important in order to ground the research in the everyday. This may include "existing technologies, regulations, practices, power relations and potential for change" (Pohl & Hirsch Hadorn, 2007:21). Achieving effectiveness is reliant on

embedding the research into a specific scientific context by connecting research efforts with the most contemporary scientific approaches in relevant disciplines (Pohl & Hirsch Hadorn, 2007).

The researcher felt satisfied that the study was in congruence with this principle, given the proposed fieldwork context of Enkanini and the valuable links and open communication channels with the research partner institutions. No slum upgrading research reports were identified which explicitly were TD in nature, however, by reading case studies, grey literature, blogs and having numerous discussions with SDI staff, it became evident that *successful* slum upgrading is inherently a TD process given its unintended adherence to the TD requirements and principles.

3. Achieve integration through open encounters

Achieving open encounters during collaborative research is reliant on the cognisance of one's own perspective and worldview amongst stakeholders and the effect that this could have in influencing outcomes. Accepting the viewpoints of all collaborators, regardless of their disciplinary backgrounds and degree of specialisation contributes towards a successful undertaking. The precise form of collaboration and mode of knowledge integration can take numerous forms and in turn affects the degree to which stakeholders reflect on their own perspectives and contributions (Pohl & Hirsch Hadorn, 2007).

The collaboration form and mode of knowledge integration will be discussed in Section 1.8.3 in the context of designing a TD design method for conceptualising the additional and intermediary energy-shelter interventions.

4. Develop reflexivity through recursiveness

As stated above, attempting to fulfil all TD requirements from the onset of a research process may become an obstacle and can compromise the quality of the research output. Approaching TD recursively, that is, creating the space for project iterations, improves the quality of the outcome by capitalising on an increased degree of reflexivity. Recursiveness as a research approach should be introduced at all stages of the research, from problem identification all the way through to bringing results to fruition; allowing for underlying assumptions to be identified, corrected and consolidated into an improved research product (Pohl & Hirsch Hadorn, 2007).

The problem identification phase of this work (Section 1.3) involved a recursive process in order to delineate a core research problem to address in this study. This process had taken 7 months and had involved considerable reflection through correspondence with the study supervisor, fellow ISUG researchers and research partners. The researcher felt confident that the research objectives had adequately been developed in reference to the core research problem, and endeavoured to continue adapting and iterating the research process as new information and dynamics emerged.

1.8 Research Design and Methods

Guidance was provided by the study supervisor as well as John van Breda, programme manager of the TsamaHUB and TD scholar, in regards to the methods which the researcher endeavoured to employ in the research process. Furthermore, the researcher participated in a TD methodology discussion forum, hosted at the Council for Scientific and Industrial Research (CSIR), which brought together academics from UCT, the CSIR and the Stellenbosch ISUG in an attempt at sharing knowledge and approaches on TD methodology.

Wickson et al. (2006) posit that the research process should be a context-informed reflection of the problems under investigation, and that concomitantly there can be no single TD research methodology. They encourage scientists to dismiss methodological reductionism through the adoption of pluralistic methodologies (Wickson et al., 2006). As such, the choice of methods in this study are both empirical (TD design process, semi-structured interviews, field visits) and non-empirical (literature review, case studies) and will be discussed according to the chronology in which they were undertaken.

1.8.1 Literature Review

A comprehensive literature review is essential to any study in order to expose the researcher to current theoretical thinking and issues, scholarly discourses and prior research (Mouton, 2008). This was the first method adopted from the stage of writing the research proposal, to deepen the understanding of the subject matter, to orientate the proposed research within the academic debates and to identify a gap within the current knowledge set. The researcher was able to draw on a significant literature repository on energy poverty and sustainable development, which had been accumulated during his BPhil (Sustainable Development) studies, yet needed to complement this with further literature in line with the intended study.

a) Search Process

Literature searches were conducted in three libraries, namely the J S Gericke Library (Stellenbosch University), the Engineering & Forestry Library (Stellenbosch University) and the Energy Research Center Library (ERC) (University of Cape Town). Appointments were made with faculty librarians at relevant libraries for guidance in the specific literature searches to increase their efficacy. This proved to be invaluable given their intimate knowledge of library IT systems and their ability to identify specific resources which had been useful to prior researchers with similar research focuses. The following list of keywords was used during the literature searches (Table 1.1).

Table 1.1: Literature Search Keywords

Informal Settlement	Slum	Upgrading	Poverty	Energy Access	Energy Poverty	Energy Poverty Nexus
Energy Infrastructure	Renewable Energy	Sustainable Energy	Decentralised Energy	Electricity	Distribution	Housing
Self-Help	Shack	Fuel Transitions	Transitions	Trans-disciplinarity	Thermal Comfort	Thermal Performance

Source: Author (2012)

Search terms were inputted into various e-databases in different combinations, e.g. '*Energy Poverty + Informal Settlement'* and '*Energy Poverty + Housing*' since this approach often rendered different results. *Science Direct* and *Academic Search Premier (EBSCO)* were found to be the most useful e-databases given the vast range of e-journals that these databases covered. In addition to database searches, specific e-journals also delivered relevant results. Through back-issue searches within these e-journals, relevant articles were identified that did not come up during an e-database search. The *Energy for Sustainable Development* and *Renewable and Sustainable Energy Reviews* e-journals were particularly useful.

Furthermore, grey literature[4] formed a significant portion of the literature search, especially as it related to the field of informal settlement upgrading, infrastructure management, tenure arrangements and general opinions on the subjects. Specifically, grey literature was drawn from blog posts on the *Slum Dweller's International Blog*, as well as research reports from the following websites: *Afesis Corplan, Land First, Project Preparation Trust* and *Urban Land Mark*. Official government policies were downloaded directly from government websites such as the *Department of Human Settlements* and the *Department of Energy.*

Whilst reading certain pieces of literature, interesting references were identified, which were subsequently followed up from the bibliography. Moreover, interviewees supplied research reports, publications and e-books. A search on *ProQuest Dissertations and Theses* and *SABinet Current & Completed Research* databases was executed in order to avoid replicating existing research and to learn from prior research attempts in line with the proposed subject area. This aspect was complimented by un-catalogued searches of prior dissertations at the ERC library.

b) Thematic Structuring

The approach to literature selection went as follows. All literature items that looked applicable to the study were downloaded into a single folder, based on the *prima facie* relevance of their titles. Subsequently, the abstracts of downloaded items were read and irrelevant material was discarded. Given the relatively wide thematic ambit of the literature search, the importance of managing the literature became a priority. The researcher devised a system where printed hardcopies would mirror precise folders on the computer. Two computer folders were created, namely 'Read' and 'Unread', which corresponded to numerous lever-arch files. Within these soft and hard literature copies, thematic categorisation was accomplished as follows: *Energy Poverty, Energy Policy, Fuel Transitions, Housing Policy, Transdisciplinarity, Sustainable Technology, Thermal Comfort, Upgrading* and *Other.* As an article was read in hardcopy, it was transferred from the 'Unread' to the 'Read' lever-arch file, an action that was mimicked on the computer. This system proved to be useful later on when it came to the data analysis phase given that the literature was already grouped thematically.

[4] "Grey literature is a term that refers to a body of materials that cannot be easily found through conventional channels such as publishers, but remain highly original" (Fieuw, 2011:10).

c) Data Analysis

Whilst reading the literature, important aspects were highlighted through short annotations on page margins. This not only proved invaluable at later stages when certain pieces needed to be re-read, but also made the process of identifying linkages across themes easier. When the time came to write Chapter 2 (the literature review), a broad outline of the structure of the literature review, in line with the thematic folder categorisation, was drawn up. All relevant literature items were revisited numerous times in order to allow for linkages across literature themes to be thematically orientated in accordance to this categorisation. This form of coding helped to identify connections between previously unrelated themes, deepening the researcher's understanding of the complex interactions between different subjects.

1.8.2 Semi-structured Interviews

Semi-structured interviews were a fundamental methodological component of this study. This method was employed during the problem identification and structuring stage, when the academic literature needed to be complimented with practical real-life experiences of local government, private sector and non-governmental organisations (NGOs) professionals. Furthermore, in designing additional and intermediary energy-shelter interventions, it was important to factor in the knowledge and perception of the ultimate users – slum dwellers – into the design process. Through semi-structured interview, their knowledge inputs were secured.

a) Interview Preparation

Interview preparations of professionals involved online searches on the organisation of the interviewee (if applicable) as well as his/her particular role in regards to a specific research interest (e.g. prior upgrading experience); whilst interview preparations for slum dwellers typically took the form of reviewing existing case studies and literature in regards to prior energy poverty interventions. The preparatory background information was used in drawing up interview discussion guides, which were composed of a balance between a small amount of relatively precise questions as well as topic headings for open-ended discussions (Willig, 2008). This allowed the researcher to obtain the specific information that was required, whilst still leaving the conversation organic enough for emerging topics to be explored.

b) Data Collection

In all cases (save for one where permission was not granted), all interviews were recorded on a dictaphone for subsequent transcription. The researcher attempted to write as little as possible during interviews, making only occasional notes on the interview discussion guide of points that needed revisiting later on in the discussion. This was in order to give the interviewee undivided attention and enabled the researcher to observe any gesticulations and non-verbal communication that may have been a signal for further topic exploration. Interviews were scheduled for mornings and the researcher kept the remainder of the day free, providing the time for immediate transcription after the close of the interview, but also allowing the researcher to capitalise on any unanticipated occurrences that could emerge out of interviews. This approach proved to be invaluable in two instances. Firstly in the case of Sean Cuff (2011 Interview), who proceeded to extend the interview by conducting two site visits, and secondly in the case of Jonathan Hodgson

(2011 Interview), who gave 6 hours of his time and a tour of his solar R&D facility. Table 1.2 is a list of Interviewees and information that was gathered from interviews.

Table 1.2: Summary of Interviews held

Date	Interviewee & Designation	Interview Focus & Key Info Gathered
15 Jan 2011	Rudi Hillermann: Manager Free Basic Services at KZN COGTA	• Free Basic Services Background • Industry Contacts
19 Jan 2011	Elie September: Stellenbosch Municipality: Electricity Department Accounts Manager	• Indigent Policy & Free Basic Services • Stellenbosch Electricity Consumption figures
3 Mar 2011	Frank Spencer: CEO of Emergent Energy (Pty) Ltd.	• Pro-poor Sustainable Technology Options • Electric Capitalism Book
18 Mar 2011	Ewald Biesenback: Electrical Engineer at AURECON Consulting Engineers	• Low Cost Housing Construction Process – Norms & Standards, Tenders etc. • Examples of Tender Documents
1 Apr 2011	Prof Ben Sebitosi: Center for Renewable & Sustainable Energy Studies	• Energy Interventions in Poor Communities
8 & 11 Apr 2011	Dawie Carolissen: Stellenbosch Municipality: Manager Informal Settlement Division	• Low Cost Housing Construction Process • Views, Opinions, challenges of UISP
20 Apr 2011	Nombulelo Zwane: Stellenbosch Municipality: Electricity Department Engineer	• Informal Settlement Electrification Process • Electrical Engineering Services Directives
4 May 2011	Riaan Meyer: Research Engineer Center for Renewable & Sustainable Energy Studies	*Informal, Unstructured Discussion* • Pro-poor Sustainable Technology Options • Industry Contacts
12 May 2011	Shawn Cuff: CEO of People's Environmental Planning NGO	• Informal Settlement Upgrading Process • Fire Retardant Construction Research
3 Jun 2011	Dr Gisela Prasad: Energy, Poverty & Development Researcher: UCT Energy Research Center	*Informal, Unstructured Discussion* • Pro-poor Energy & Housing initiatives • Industry Contacts
11 Jul 2011	Rudi Hillermann: Manager Free Basic Services at KZN COGTA	• Housing Subsidy Flows, Free Basic Alternative Energy Subsidy • Industry Contacts
18 Jul 2011	Mark Misselhorn: CEO Project Preparation Trust	• Emergency Housing Guidelines • Informal Settlement Tool kits

29 Jul 2011	Jonathan Hodgson: Owner of Specialized Solar Systems (Pty) Ltd.	• Offgrid, sustainable Energy Technology options: DC Multigrid System • Institutional Design for Technology rollouts • Training manuals, Technology data sheets
1 – 8 Aug 2011	5 Enkanini Informal Settlers	• Energy Usage, Energy spend • Informal Shelter design process & opinions
2 Sept 2011	Malcolm Worby: Earth-building specialist & architect at Malcolm Worby CC	• Sustainable Informal Shelter Construction • Online Resources

Source: Author (2012)

c) Data analysis

As mentioned above, interview transcriptions were conducted on the interview day itself, or the day following, to ensure that impressions and reflections of the interview were still fresh. There are different ways to transcribe interviews, depending on the nature of the research and intended use of the data. Given that the researcher was interested in the content of the interviews, there was no need to conduct verbatim transcriptions or to record non-linguistic features of speech (Willig, 2008). Instead, the researcher synergised the discussion whilst transcribing, drawing out key points that needed clarification, or warranted further investigation. This approach was a more efficient use of time and allowed for simultaneous thematic coding of the interviews.

1.8.3 Transdisciplinary Design Process

> *"Transdisciplinarity contributions involve a fusion of disciplinary knowledge with the know-how of lay-people that creates a new hybrid that is different from any specific constituent part"* – (Lawrence, 2006:542)

In order to conceptualise additional energy and shelter interventions, the researcher commenced with a TD design process in order to draw on the knowledge set of a variety of disciplines and experiences that could materially shape an outcome.

a) Stakeholder Identification

Pohl and Hirsch Hadorn (2007) outline a tool that can be employed to identify the actors and disciplines necessary in order to satisfy the requirements of TD. Composed of a simple matrix of TD requirements in rows and actors/disciplines in columns, the tool provides practitioners with an overview of the required resources necessary to meet the intended research objectives. The researcher was satisfied that the overall approach of this study was in congruence with the TD requirements, and thus adapted the tool in order to reflect the specific disciplinary requirements needed for the intermediary energy and shelter design phase (Table 1.3).

Table 1.3: Stakeholder and Disciplinary Matrix

Stakeholder		**Discipline**				
Name	**Discipline**	**Structural Design**	**Ecological Design**	**Materials Knowledge**	**Liveability & Comfort**	**Thermal Performance**
Enkanini Residents	Lived Experience	X		X	X	
Cindy Bester	4th year Mechanical Engineer Student	X		X		
Shawn Cuff	Architect and Civil Society Practitioner	X	X		X	X
Colette Fransolet	Industrial Design Student	X		X	X	
Bernhard Lembeck	Ecological Paint Manufacturer		X	X		
Mugendi M'Rithaa	Industrial Design Academic	X		X	X	
Mark Swilling	Sustainability Academic	X	X	X	X	
Malcolm Worby	Architect & Earth Building Specialist	X	X	X		X
ISUG Fellow Researchers	Economics, Sociology				X	
	TOTALS	7	4	7	6	2

Source: Author (2012)

Five key disciplinary foci were identified, which were matched to the knowledge that various stakeholders could provide. These were Structural Design, Ecological Design, Materials Knowledge, Liveability & Comfort and Thermal Performance. This simple exercise gave an overview of the strengths and weaknesses of the TD team that was assembled. The researcher proceeded to find supplementary sources of information in order to bolster the weak points in the TD team, which were Thermal Performance and Ecological Design. Fortunately, these areas have received significant attention in academic literature, allowing the researcher to inform himself of various interventions and approaches in this regard through self-study.

b) Stakeholder Collaboration Approach

Managing the extraction, blending and synergising of knowledge from various stakeholders was the next challenge. Pohl and Hirsch Hadorn (2007) discuss the four socio-cognitive frameworks of Rossini and Porter (1979) for integrating interdisciplinary research (Figure 1.1). These are meant to guide the facilitation between a complex range of actors and provided an oversight by which to assess the way in which their knowledge inputs could be integrated.

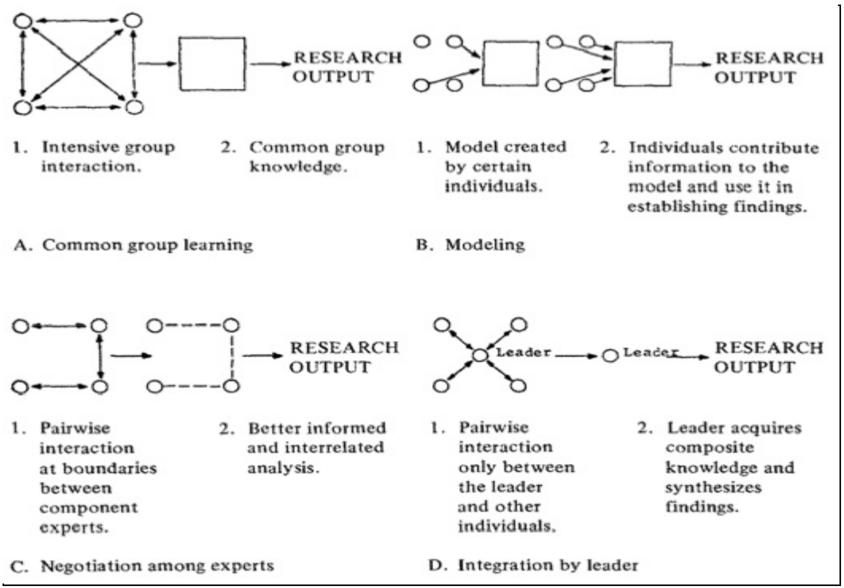

Figure 1.1: Socio-cognitive frameworks for collaboration
Source: Rossini and Porter (1979)

The researcher was drawn to the *Common Group Learning* Framework, which deemphasises individual expertise in the project outcome. It was identified as a more horizontal and democratic way in which to approach the research (Rossini & Porter, 1979), especially given the objective of including community members in the design process. This model appeared to be the most congruent with Pohl and Hirsch Hadorn's (2007) assertion that the most important collaboration principle in TD was that of "open encounters" (Pohl & Hirsch Hadorn, 2007:57).

Practically though, it was found that the *Common Group Learning* model was difficult to implement given the challenge of synchronising the demanding schedules of a wide range of professionals and community members, which typically only had time in the evenings. Furthermore, it was realised that the nature of the design phase was more technically demanding than originally anticipated and that the use of this framework would have "lowered the depths of disciplinary analysis" (Rossini & Porter, 1979:74). The *Integration by Leader* framework thus seemed the most feasible, since it allowed stakeholders to provide selective inputs in accordance to their routine demands. Rossini and Porter (1979) posit that this model precludes contact between individual stakeholders, given the 'hub-and-spokes' pattern of communication. The researcher however chose to disregard this notion, preferring instead to meet with different stakeholders regarding a particular design aspect under consideration, as and when schedules allowed it. These interactions proved to be far more fruitful through the creative synergising and problem solving that can only occur through face-to-face encounters between groups of stakeholders.

c) Construction Process

The TD design process gave rise to the design of two additional energy and shelter interventions, which involved the retrofitting of an existing shack and the construction of a new shack in accordance to ecological and sustainable design principles with the addition of a DC Multigrid system. These interventions are called 'Retrofit' and 'iShack' (improved shack) respectively. Both interventions were piloted in Enkanini and were thus subject to a construction process. It was important to include people with context specific knowledge (shack dwellers) into the improved shelter construction processes, given the limited knowledge of the researcher in this regard.

The researcher decided to be guided by the construction process itself, that is, by solving unanticipated design problems as they emerged during the construction. In a paper titled *The role of lay people in the production and dissemination of scientific knowledge,* Callon (1999:82) outlines theoretical models which concern themselves with the "degree of involvement of lay people in the formulation and application of the knowledge and know-how on which decisions are based". Of the three models discussed, the researcher was guided by the core tenets of the *Coproduction of Knowledge Model*, which emphasises a) the central role of non-specialists knowledge and know-how; b) the constant, dynamic interaction between specialists and lay people; c) the possibility of collective learning; d) the equal footing between specialists and concerned groups (assimilation of lay people, parties intent on benefiting from the research); and lastly e) the recognition that interested groups should gain from their actions (Callon, 1999:89-93). The researcher endeavoured to ensure that the construction process would be equally informed by the collective TD design process and the valuable construction lay knowledge that was at hand.

1.8.4 Empirical Data and Thermal Comfort Methodology

In order to test the efficacy of the Retrofit and iShack interventions, a temperature measurement process was required which was in congruence with an academically acceptable methodology. During the research design phase, Professor Martin Kidd at the Center for Statistical Consultation at Stellenbosch University (CSC) was consulted where the researcher discussed the objectives of the study and the quantitative data that was required in order to meet these objectives. The required data were indoor and outdoor temperatures over time, which Professor Kidd suggested be recorded at 15-minute intervals, in order to render a high degree of explanatory ability. The researcher chose to analyse the dwelling interventions according to a) thermal performance and b) thermal comfort performance.

Thermal performance refers to a statistical comparative analysis of the correlation between Indoor and Outdoor Temperature, their absolute levels, magnitude of differences and rates of change over time. Thermal comfort performance goes beyond this approach, by including the human dimension, effectively adding an objective component to the dehumanised thermal performance metrics. The researcher felt comfortable using the thermal performance measures that Professor Kidd had developed for this particular study, yet needed to find a suitable thermal comfort performance methodology which could suit informal dwelling environments within the South African context.

a) Thermal Comfort Methodological Underpinnings

Thermal comfort is defined as "a state in which there are no driving impulses to correct the environment by behaviour" (Djongyang et al., 2010:2627). It thus describes a condition whereby occupants of a building are satisfied with the thermal conditions of their environment. The indoor comfort environment is a function of numerous variables which include the dry bulb temperature[5], relative air humidity, air movement, radiation, human metabolic rate, amount of clothing people wear, individual levels of acclimatisation, age, body type/condition, health condition and the amount of negative or positive ions present in the air (Holm & Engelbrecht, 2005).

Standards for modern buildings[6] attempt to distil some of these variables into objective measures in order to provide a uniform measure of thermal comfort. Yet, thermal comfort is a complex and subjective reaction to the immediate environment and still no absolute standard for the metric exists (Djongyang et al., 2010). Furthermore, the international prescriptive standards concern themselves with formalised built structures, artificially ventilated and cooled, and as such are not suitable for providing an objective thermal comfort measure for informal structures, such as shacks, which are both naturally ventilated and composed of a variety of materials and designs.

b) Towards a suitable thermal comfort measure for informal structures

Broadly speaking, the existing measures of thermal comfort are categorised by two different approaches. The *rational indices approach* involves the simultaneous recording of comfort variables (temperature, humidity and airflow) and occupant level of comfort at various time intervals. A mean comfort vote is determined through comfort responses, which are recorded on a set of subjective sensation rating scales (e.g. ASHRAE or Bedford scales) with values ranging between -3 (Cold) and 3 (Hot) (Nicol & Humphreys, 2002). Rational indices studies are conducted in steady-state conditions where participants are exposed to a varying set controlled environmental conditions and results are subsequently used to predict conditions in which occupants will be comfortable elsewhere (Djongyang et al., 2010).

Comfort studies have however demonstrated that results from controlled climate chambers do not correlate with actual field observations (Humphreys 1994; Nicol & Road 1996; De Dear et al., 1997; Auliciems & Szokolay 1997 in Holm & Engelbrecht, 2005). They fail to account for context and the actions that humans might take in an attempt to acclimatise to a given environment. The *adaptive models* account for these complexities which arise out of the interaction of humans with their indoor environment (Djongyang et al., 2010). "Adaptation includes *adjustment* (behavioural/technological changes to heat balance), *habituation* (psychological adaptation, changing expectations), and *acclimatisation* (long-term physiological adaptation to climate)" (Holm & Engelbrecht, 2005:11, italics original). As such, the comfort ranges according to adaptive models are wider, since they incorporate the active and passive strategies that occupants employ in different time frames in order to feel comfortable in a given environment. Models that allow for adaptive behaviour would be more attuned to an informal settlement setting, since dwelling sizes are typically smaller with little buffering from the elements. Shack dwellers respond directly to climatic variations, something that the researcher observed in Enkanini, e.g. when temperatures were cold, whole families would literally hibernate together in bed throughout the day to escape the cold; or on hot days, children

[5] Dry Bulb Temperature (DBT) is the temperature of a standard thermometer, such as the figure broadcasted on television and radio weather services.

[6] E.g. International Standards Organisation standards (ISO 7730 & ISO 10551) and the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) standards.

would run around without clothes on and some women decided to cook outside to prevent additional heat-gain inside the shack (Keller, 2012).

In a paper titled *Practical choice of thermal comfort scale and range in naturally ventilated buildings in South Africa*, the authors review major indices and adaptive methodologies in an attempt to determine the most applicable approach for South African free-running, i.e. non air-conditioned buildings (Holm & Engelbrecht, 2005). They find that for thermal comfort ranges, the Net Effective Temperature (ET*) is the most applicable, a measure described as "the DBT [dry bulb temperature] of a uniform enclosure producing the same heat exchange by radiation, convection and evaporation as the given environment. It allows for body, clothing and space interaction" (Holm & Engelbrecht, 2005:10). A comparative analysis of the outdoor ET* and Dry Bulb Temperature (DBT) of naturally ventilated South African buildings however suggests that there is a negligible difference for the indoor comfort range between the two metrics between the range of 17,8°C and 29,5°C at an altitude below 3000m above sea level. As such, the authors recommend the singular use of DBT in the determination of indoor thermal comfort in South Africa, given the ease of computation and accessibility of these figures (Holm & Engelbrecht, 2005).

These findings are in alignment with those of Nicol and Humpfreys (2002), who found that in naturally ventilated buildings, using outdoor temperature alone in the calculation of comfort temperature is acceptable given people's adaptive actions to acclimatise to altering climatic conditions. The authors came to this conclusion through an analysis of the data presented in Humpfreys (1970) and the ASHRAE 1998 database, where the authors found a near-linear relationship between outdoor temperature and comfort temperature, with correlation coefficients of 0.97 and 0.95 (in Nicol & Humpfreys 2002).

c) Determining the Dry Bulb Neutrality Temperature (TnDBT)

The neutrality temperature for a given measurement approach is defined as "the temperature at which the subject feels neither too hot nor too cold" (Holm & Engelbrecht, 2005:12). This is important to determine, since it gives an indication of the dwelling comfort temperature range. The Dry Bulb Neutrality Temperature (TnDBT) is calculated as follows:

$TnDBT = 17{,}6 + 0{,}31 \times T_O$ [Equation 1]

With 17,8°C < Tn < 29,5°C, valid up to altitudes of 3000m above sea level;

T_O = average outdoor DBT of the day, month or year;

and DBT = average of maxima and minima (Holm & Engelbrecht, 2005).

Stringency standards in the form of acceptability bands allow for deviations above or below the TnDBT for differing building qualities whilst maintaining indoor comfort (Table 1.4). Acceptability is defined as the "percentage of an average climate adjusted population, wearing suitable clothing, feeling neither to [sic] hot or to [sic] cold", whilst building quality implies "the building's potential income from rent" (Holm & Engelbrecht, 2005:13). A higher building quality thus implies an above average potential to generate rental income. Whilst thriving rental markets exist in many informal settlements, for the purposes of this analysis, the lower building quality with relevant stringency standard will be applied. This implies that an overall variance of 7°C from the TnDBT is acceptable, leaving 80% of the population still thermally comfortable. This appears to be acceptable, given Nicol and Humpfreys (2002) band of ±2°C for non-adaptive circumstances (Nicol & Humpfreys, 2002).

Table 1.4: Building Quality Stringency Standards

Building Quality	Comfort Range Acceptability	Tolerance
Higher	90%	TnDBT ± 2,5°C
Lower	80%	TnDBT ± 3,5°C

Source: Adapted from Holm and Engelbrecht, (2005:13)

Box 1: A Practical Example: Calculating Thermal Comfort Acceptability Bands

Assuming the maximum and minimum outdoor temperature on a given day are 30,8°C and 12,4°C respectively, resulting in an average daily temperature of 21,6°C.

1. Using Equation 1, TnDBT = 17,6 + 0,31 x 21,6°C = 24,6°C.
2. Check that TnDBT is 17,8°C < Tn < 29,5°C and data measurements < 3000m above sea level.
3. Apply 80% Comfort Range Acceptability of TnDBT ± 3,5°C. Thus, 24,6°C ± 3,5°C renders indoor thermal comfort on the given day at 21,1°C < TnDBT < 28,1°C
4. Check indoor temperature measurements whether they stayed within this band on the given day.

d) Measuring Equipment

WH3081 Wireless Weather Stations and Data Loggers were installed in all three participating shacks in order to record individualised temperature observations. This equipment has two separate components – an internal unit comprising a data logger and display unit for indoor observations and an assemblage of various measuring devices mounted on a single bar positioned on the exterior for outdoor observations (Figure 1.2). The two units communicate via a synchronised radio signal, up to a distance of 100 meters. The internal unit was affixed slightly below the ceiling on the central structural support to avoid tampering from children and to record data from the center of the household. Similarly, the external unit was placed in the center of the roof in order to avoid tampering and possible theft. Prevention of radio signal interference between different systems was necessary given the proximity of the shacks. This was achieved by assembling, activating and coupling each system in a separate area, prior to installation.

Figure 1.2: Indoor Display and Data logger (left) and roof-mounted Weather Station (right)
Source: Photograph by Author (2012)

e) Data Collection

A two month time frame of data observations was deemed sufficient given that this study intends to show the effect of improved dwelling construction and energy interventions and does not intend to derive results with predictive abilities. Practically, this also reduced the inconvenience and privacy infringements to the participating householders that would result from frequent data withdrawals and equipment checks. Data was downloaded every three days, in order to ensure that a possible system malfunction would not result in a discontinuous data set. The measuring equipment required the use of a laptop computer, in order to transfer the data on location, as opposed to removing the unit and transferring data offsite. The downloaded data were analysed immediately after retrievals to check the integrity of the new recordings and to action any changes that were required.

1.8.5 Case Study

Having demonstrated the Retrofit and iShack potential at improving thermal performance and thermal comfort performance, the researcher proceeded to analyse the space within the current human settlements and energy policies where additional incremental informal shelter and sustainable energy responses could be supported. It was found that the energy policy terrain currently does provide the space for the introduction of sustainable energy transitions, but that the human settlements policy has limited scope. An attempt was made at deriving a set of principles that could inform a human settlements policy iteration towards one that *does* create the supporting environment where energy poverty alleviating incremental shelter transitions could be pursued.

The case study approach is the most suitable given its ability to “capture reality in greater detail and that it is possible to analyse a greater number of variables compared to other approaches” (Galliers, 1992 in Ruddin, 2006:801) – an important consideration given the enormous complexities involved in slum upgrading. The researcher conducted numerous literature searches in regards to policy precepts and slum upgrading, yet only found stand-alone case studies, or decontextualised policy framework recommendations. Combining a case study with an exercise at extracting a set of core principles that were key to its success would be an effective way to inform future policy changes.

a) Case study selection

The strategy for selecting a suitable case study was inspired by Flyvbjerg's notion of the *paradigmatic case,* the purpose of which is "to develop a metaphor or establish a school for the domain that the case concerns" (Flyvbjerg, 2006:230). "It operates as a reference point and may function as a focus for the founding of schools of thought" (Flyvbjerg, 2006:232). The challenge with the paradigmatic case study approach is the lack of sampling standards, since the case itself sets the standard. In addressing this challenge, Flyvbjerg (2006:232) suggests that "all that researchers can do is [to] use their experience and intuition to assess whether they believe a given case is interesting in a paradigmatic context and whether they can provide collectively acceptable reasons for the choice of case". The researcher reviewed numerous cases and assessed these on their individual merits, including cases where upgrading attempts had failed, since this can sometimes be more instructive.

A case study of the Thai version of the South African UISP, called The Baan Mankong programme, as well as the Bang Bua community upgrade (implemented under the programme) was decided on. Three factors informed the choice of case study: Firstly, the Baan Mankong programme is policy enshrined and takes a programmatic approach, in line with the UISP, making cross-reference comparisons easier. Secondly, the profile of intermediaries that were pivotal to the Bang Bua community upgrading success are similar to those on the current South African upgrading scene in terms of academic institutions, local government and government supporting institutions. Furthermore, Baan Mankong's supporting NGO (Asian Coalition for Housing Rights) is part of the same umbrella organisation (Slum Dwellers International) as South African grassroots upgrading support organisations (Informal Settlement Network; Community Organisation Resource Center). Lastly, South Africa and Thailand are similar in that both countries have significant urban slum communities and, contra to many other developing countries, have legitimate states that make housing subsidies available.

b) Generalisability of single Case Studies

"Generalization is about the rationale for transferability" and that "to argue one's analysis of a case is valid is implicitly to claim that the analysis holds for comparable cases" (Ruddin, 2006:800). Some scholars have argued that single case study research does not offer generalisable results as these may reflect idiosyncratic aspects of a particular case which would impinge on its ability to be adapted to other instances (Eisenhardt, 1989; Lindegger, 2006). The researcher was concerned that the intention to derive a set of general principles from one case study would compromise the methodological rigour of the study. In response to this criticism however, Ruddin (2006:799) states that "it is correct that the case study is a comprehensive examination of a single example, but it is not true to say a case study cannot provide trustworthy information about the broader class".

Ruddin (2006:799) posits that "an analyst should try to generalise results to "theory"; analogous to the way a scientist generalizes from experimental results to theory […]". In line with this argument, Flyvjerg distinguishes between 'hard' theory, which comprises the qualities of predictability and clarification; and 'soft' theory which is used for testing hypotheses or proposition (Flyvbjerg, 2006). In the absence of a central 'theory of successful upgrading', the researcher realigned this theoretical requirement by replacing it with the current South African 'theory of upgrading' in the form of its current upgrading policy, the UISP. In generalising the Baan Mankong case study principles and applying them to the UISP through a 'soft' theory approach, an opportunity is created to interrogate the premises which underlie the UISP's foundation. Through a causation map, the principles which enabled the Baan Mankong success are linked to the shortcomings of the UISP, revealing ways in which the adoption the principles to the South African context could shape a more beneficial outcome.

1.9 Limitations

> *"Questions that lead to research projects have their own intellectual history. They are sometimes influenced by the personal biography of the authors asking the questions"* – (Baccini & Oswald, 2007:79).

In approaching this study there was an awareness of certain limitations that could affect the research process and results:

a) This study was the researcher's first foray into the world of policy and government, having previously worked in the private sector with a business degree. Awareness was exercised not to view the problems and opportunities encountered in this study through a reductionist and typically neo-liberal economic prism which favours cost minimisation and efficiency maximisation approaches. The researcher continually had to challenge these notions and be open to alternative ways of thinking.
b) As a middleclass white South African conducting research in an informal community such as Enkanini would bring about unavoidable class, language and cultural barriers, which the researcher acknowledged would have some bearing on the study and its results.
c) It would be ambitious and unrealistic to claim that an 18 month research process adequately captured all elements of an inherently complex subject matter – in situ informal settlement upgrading and energy poverty alleviation.

1.10 Thesis Outline

The outline of this work follows the three TD knowledge types as well as the chronology of research objectives outlined above.

Part A: Systems knowledge
In Chapter 2, a review of the South African human settlements, pro-poor energy policy and energy poverty nexus literature sets the context within which to construct a stylised energy-shelter trajectory for informal households. This reveals a current 'All-or-Nothing' approach to shelter and energy infrastructure provision. Using the trajectory, two additional and intermediary energy shelter and sustainable energy interventions are defined, namely the Retrofit and iShack.

In Chapter 3 further systems knowledge is generated through a review of sustainable energy technologies currently available on the market as well as existing improved shelter research and practice. A brief review of the Fuel Transitions literature provides a better understanding of the complexities involved in transitioning to improved energy technologies. A DC Multigrid system is chosen as the most appropriate sustainable energy technology.

Part B: Target Knowledge

In Chapter 4, the Retrofit and iShack are designed and constructed by means of a Transdisciplinary design process. Through a social process a suitable site and participants are identified; an administrative process results in municipal and community leadership consent; and a legal process ensures that project particulars are reduced to agreements. Costs, quantities and other particulars in regards to the interventions are discussed.

In Chapter 5, the Indoor and Outdoor temperature measurements are statistically analysed according to their thermal performance and thermal comfort performance. Through user feedback, the statistical results are further complimented to gain a user perspective on the energy poverty alleviating potential of the interventions.

Part C: Transformation Knowledge

In Chapter 6, the pro-poor energy and human settlements policy is revisited to identify the spaces where the additional energy-shelter interventions could be supported. Both policy approaches hold this potential, however, in order to be effective at scale, a dedicated human settlements policy space needs to be created. Through a case study of the Thai Baan Mankong slum upgrading programme, an attempt is made at deriving a set of upgrading principles with which to inform a necessary South African human settlements policy iteration that could enable additional and intermediary energy-shelter transitions.

In Chapter 7, the main arguments of this study are reviewed and recommendations for future research are offered.

Part A: Systems Knowledge

"System's knowledge is knowledge about the current system or problem situation. This recognises that there may be uncertainties about the genesis of the problem, along with different interpretations depending on the goal of participants" – (Hadorn et al. 2008 in Cronin 2008:12).

Chapter Two: Literature Review

2.1 Introduction

The latest iteration of South Africa's human settlements policy came in 2004 in the form of the *Breaking New Ground* (BNG) policy, shifting the focus towards the creation of 'sustainable human settlements' through, amongst other things, the *in situ* upgrading of informal settlements. Whilst progressive in nature, the policy has enjoyed little political support (Pithouse, 2009) and has had little traction on the ground. None of the 9 provinces piloted the programme as set out in BNG (Huchzermeyer, 2009) and only a few remote cases of in situ upgrading, in accordance to the policy, have been reported. Instead, the proliferation of apartheid state city planning, with segregated urban landscapes has been perpetuated through low-cost housing developments (Bradlow, et al., 2011; Landman & Napier, 2010:300; Huchzermeyer, 2009). South Africa's cities remain unequal and fragmented spaces, inaccessible to many of its poor citizens who continue to be located in sterile, uniform housing developments on the urban perimeter or in informal settlements.

Following is a review of the South African post-apartheid human settlements policy (Section 2.2) and pro-poor energy policies (Section 2.3) as they relate to the upgrading of informal settlements and energy access promotion respectively. Both policy approaches are informed by the objectives of poverty alleviation and the promotion of equality (DME, 2001; DoH, 2004). The primary human settlements policy tool – the Upgrading of Informal Settlements Programme (UISP) – as well as the energy policy approaches have significant shortcomings which directly affect the energy choices of the urban poor, leaving many in a state of energy poverty. An exploration of the energy poverty literature (Section 2.4) deepens an understanding of this phenomenon by elucidating the nexus between energy and poverty.

Through a synthesis of the discussion (Section 2.5) it emerges that the policy sanctioned shelter and energy infrastructure options available to informal settlers may be described as an 'All or Nothing' approach, the consequences of which being prolonged periods of deepening energy poverty. A stylised Energy-Shelter trajectory, composed of discrete policy-enabled energy and shelter transitions, helps to identify the spaces where additional, intermediate and incremental energy poverty alleviating responses can be achieved through shelter and energy technology improvements.

2.2 Informality and Housing Policy in South Africa

2.2.1 Informality and the South African City

> *"Shacks are a material expression of a popular response to a deeply entrenched social crisis – they are not the crisis"* – (Pithouse, 2009:11).

> *"… Unplanned settlements must be recognized as a benign expression of human need…"* – (Huchzermeyer, 2009:63).

We live in a world that is majority urbanised (Rahman, 2011). Increasing urban populations place immense pressures on governments, especially in the developing world, to improve the quality of housing in existing slum settlements as well as providing land and housing to those without shelter (Bredenoord & Van Lindert, 2010). Enormous strain is placed on existing city infrastructure and services as some cities in the global south experience annual population growth rates in excess of 10% (Wekesa et al., 2011). These, and other pressures, lead to the emergence of informal settlements, characterised by dehumanising living conditions brought about by deficient infrastructure services, high population densities and inadequate housing (Majale, 2008). For people living in informal settlements, tenure insecurity adds towards a constant threat of evictions (Wekesa et al., 2011). Participation in the formal economy is often limited (Klug & Vawda, 2009), resulting in the emergence of home-based and Small and Micro Enterprises (Bredenoord & Van Lindert, 2010). Yet unemployment levels often remain high and many slum dwellers, employed in the informal sector, are survivors as opposed to entrepreneurs (Watson, 2009), reliant on multiple livelihoods strategies in order to survive the harsh realities of slum living (Klug & Vawda, 2009).

Contra to the rest of Sub-Saharan Africa, characterised by predominantly rural populations, South Africa is 64% urbanised (Wolpe & Reddy, 2010). Rapid urbanisation is often cited as the primary cause for informality, yet research in South Africa's 3 largest metro's has shown that, on average, 53% of informal settlers had left backyard dwellings, 20% had relocated from other informal settlements and 7% had come from domestic servants quarters – all intra-urban relocations (Misselhorn, 2008). Post-apartheid spatial reshuffling and movement are still underway (Borchers et al., 2008), yet clearly there is more to the picture than purely rural-urban migrations. Wekesa et al. (2011) attribute the proliferation of informal settlements in developing countries primarily to market and public policy failures. City planners criminalise informal settlements, whilst sanctioning middle class property development and speculation (Watson, 2009). Unused and undeveloped land is often chosen, where resistance and media attention is likely to be least. In South Africa's case this might be on the edges of existing townships or former racial buffer zones (Huchzermeyer, 2009).

A primary target of the South African Government, as specified in its human settlements policy, is the upgrading of all its informal settlements by 2014 (DHS, 2009a). In reality though, informality is likely to remain a central facet of the urban landscape given that the share of South African's living in informal housing is growing at a faster rate (3.5%) than those living in formal dwellings (2.5%) (Wolpe & Reddy, 2010). This is evidenced by a rising housing backlog, which despite impressive housing delivery statistics – 2.9 million houses between 1994 and 2010 (DHS, 2010) – has increased from 1.5 million to 2.1 million people in the same time span (Bradlow et al., 2011). Whilst a growing population and decreasing household sizes might account for a large part of this rising proportion, the glaring reality is that the share of South Africans without formal shelter is increasing (SACN, 2011).

South Africa's constitution affords every citizen the right to 'adequate shelter', as affirmed in Chapter 26 of the Bill of Rights (Republic of South Africa, 1996:1255). This mandate has informed the evolution of the country's two distinctive phases of post-apartheid housing policy, specifically in regards to the approach to informal settlements.

2.2.2 Housing Policy from 1994 to 2004: 'Quantity over Quality'[7]

a) Background

The first democratic government drafted the Reconstruction and Development Program (RDP) in 1994 – a strategic policy masterplan intended to address the poverty and inequality of the apartheid legacy by placing the country on a path of high and sustainable growth (Republic of South Africa, 1994). The policy recognised the fact that the lack of housing had reached crisis proportions in 1990 and subsequently prioritised the delivery of housing by setting the target of providing 1 million houses in 5 years (ANC, 1994). This lead to the drafting of the Housing White Paper of 1994, after a housing summit and record of understanding between all dominant stakeholders (Huchzermeyer, 2001). Ideologically, the representatives were divided into two groups. On the one side was big business, advocating a capital subsidy based freehold site and service approach, and the other group, the Mass Democratic Movement (an amalgamation of the ruling political party, trade unions and civil society organisations) promoting a state-built rental model (Charlton & Kihato, 2006; Pithouse, 2009).

The resulting compromise between the stakeholders was the advancement of a "'starter house' added onto the site and service services model" (Pithouse, 2009:7). Financing the new houses at scale was to commence by means of a capital subsidy, which became the cornerstone of the new policy approach (Huchzermeyer, 2001). Beneficiaries, with household incomes below R3500 per month were entitled to a once-off grant for land, services and a top structure (Landman & Napier, 2010). Of the four forms of capital subsidies available under the policy at the time (see Wilkinson, 1998), the project-linked subsidy became the most favoured in that it allowed the promulgation of "large-scale developments of uniform, free-standing, mostly one-roomed houses with individual freehold title in standarised township layouts located on urban peripheries" (Huchzermeyer, 2001:306). On the subject of housing typologies, Del Mistro and Hensher (2009:334) observe that a contributing factor to the chosen dwelling design was the "Memory of Apartheid Style Housing Interventions". Single, detached dwellings on a plot of land with freehold title became the only acceptable housing option.

[7] (Tomlinson, 2006:85)

Many viewed this initial housing policy approach as a reflection of the 'pacted nature' of the democratic transition between the private sector and both the outgoing National Party and the incoming ANC-led government (Huchzermeyer, 2001; Charlton & Kihato, 2006). It favoured a neoliberal, market-driven approach to informal settlement 'eradication' and free standing housing provision through profit-driven contracted professionals (Bradlow et al., 2011; DAG, 2007) as opposed to state-run social housing proposed by the Mass Democratic Movement (Charlton & Kihato, 2006).

From a project management perspective, the approach enabled the rollout of houses at scale with minimal beneficiary participation in the design, layout or construction of their future living environments. Indeed, the policy was wholly supply-side focused (Wilkinson, 1998; Klug & Vawda, 2009) with contractors employed to "carry out specific tasks such as applying for subsidies on behalf of communities, identifying and servicing land, and building rudimentary top structures" (Tomlinson, 2006:98). These resultant structures were dubbed RDP housing, named so after the policy under which they were initiated (Landman & Napier, 2010).

b) Problems / Shortcomings

The apparent shortcomings of the housing policy soon became apparent in that they turned communities into passive and expectant recipients of turn-key housing (Landman & Napier, 2010; Sanya, 2010; Bradlow et al., 2011). "The RDP housing program has created false illusions for the millions who live in hope of a free house that will likely never come" (SDI, 2011:2). Secondly, the housing construction was often of shoddy and substandard quality (Tomlinson, 2006). Driven in part by increasing minimum standards and the relative decrease of the housing subsidy due to inflationary pressures, contractor profits were being squeezed, which they addressed through lowering the quality of the final housing product (Pithouse, 2009). The National Homebuilder's Registration Council (NHBRC) was launched in 1995 in order to protect consumers from shoddy construction through a construction monitoring and warranty function (Huchzermeyer, 2001). Its mandate to provide protection over the subsidy-market was extended in 1998, however this only came into effect in 2002, by which time 1.6 million homes had already been build, thus falling outside of its warranty protection (Tomlinson, 2006). A little over 35% of state housing is reported to have problems associated with their construction (SACN, 2011). The associated health risks of damp environments and structural problems plague households to this day, especially since many are unable to afford repairs (Govender et al., 2011). Thirdly, housing settlements were often located on the urban periphery where space was available, land was cheap and removed from the powerful business interest of the inner city (Huchzermeyer, 2001; Goebel, 2007). Space reserved for township establishment under apartheid was also developed (Pithouse, 2009). The choice of land thus contributed towards a low-density urban sprawl removing citizens from social amenities and economic opportunities, effectually deepening the cycle of poverty (Tomlinson, 2006; Huchzermeyer, 2009). The adverse effects of compromised location were exacerbated by a lack of co-ordination between governmental spheres in the provision of public services such as libraries, schools, transportation links and clinics (Pithouse, 2009). Instead of addressing the legacy of apartheid socio-spatial engineering, the policy thus contributed towards further social fragmentation, spatial marginalisation and perpetuation of class inequalities reminiscent of the apartheid state (Huchzermeyer, 2009; Klug & Vawda, 2009). Fourthly, the implementation of the housing policy was often corruption-riddled, especially in the allocation of houses, subsidies and developer contracts (Cohen, 2009; Pithouse, 2009).

"The technocratic reduction of the urban question to a housing question by the state and much of civil society after apartheid…" was evidenced by the one-dimensional and self-satisfying focus on the number of housing units delivered (Pithouse, 2009:8). The failure of the initial policy, evidenced by the persistence and continued growth of informal settlements, became apparent in 2004, when a 10-year review of South African housing policy was conducted (Huchzermeyer, 2006). The states response came in the form of a revolutionary new housing policy, called *Breaking New Ground: A Comprehensive Plan for the Development of Sustainable Human Settlements* (henceforth called 'the policy' or 'BNG' interchangeably), which sought to address many of the shortcomings of the original RDP housing policy.

2.2.3 Housing Policy post-2004: Sustainable Human Settlements and Informal Settlement Upgrading

> *"The dominant production of single houses on single plots in distant locations with initially weak socio-economic infrastructure is inflexible to local dynamics and changes in demand. The new human settlements plan moves away from the current commoditised focus of housing delivery towards more responsive mechanisms which addresses the multi- dimensional needs of sustainable human settlements"* – (Department of Housing (DOH), 2004:8).

a) Breaking New Ground

Inherent in the new BNG policy was a paradigmatic shift from the provision of basic shelter towards the creation of sustainable human settlements, which the policy defines as "well-managed entities in which economic growth and social development are in balance with the carrying capacity of the natural systems on which they depend for their existence and result in sustainable development, wealth creation, poverty alleviation and equity" (DoH, 2004:11). In order to action development accordingly, the policy sets out an extensive plan to promote densification and integration of urban areas through enhanced regulatory mechanisms, planning functions and financial incentives. Apartheid spatial fragmentation is addressed by locating new housing projects on well-positioned land through the release of state owned land or the expropriation (at market value) of private land. The stipulation for the integration of economic and social infrastructure sees a departure from the housing-only focus towards a holistic approach dedicated to supporting the livelihoods of communities (DoH, 2004). BNG furthermore paved the way towards the creation of an Informal Settlement Upgrading Programme (henceforth called 'the programme' or 'UISP' interchangeably), designed to integrate informal settlements "into the broader urban fabric to overcome spatial, social and economic exclusion" (DoH, 2004:12).

b) Upgrading of Informal Settlements Programme

In line with international best practice, a phased in situ upgrading approach for informal settlements located on suitable land (with relocations only as a last resort) was put forward with a dedicated subsidy mechanism (Huchzermeyer, 2006). This financing instrument was matched to a prescribed project lifecycle, a 4-Phased incremental approach which is outlined in Part 3 of *The National Housing Code of 2009* (DHS, 2009b). The project phases are to proceed as follows (DHS, 2009b):

- *Phase 1: Application.* Municipalities submit Interim Business Plans to Provincial Government, which include relevant details from the Integrated Development Plans and Housing Development Plans, as well as prefeasibility studies. Approval is subject to the review of the provincial Human Settlements MEC, after which the next phase commences.
- *Phase 2: Project Initiation*. Municipalities receive funding for the acquisition of land (where necessary), profiling of the socio-economic and demographic characteristics, installation of interim services and pre-planning studies – including an Environmental Impact Assessment.
- *Phase 3: Project Implementation*. Municipalities submit a Final Business Plan, which includes all considerations and time frames relevant to Phase 4. Upon approval by the MEC, funding is made available for project management capacity, the establishment of Housing Support Services[8], planning processes, formalisation of land occupational rights, relocation assistance, land rehabilitation, permanent municipal infrastructure installation and the construction of social, economic and community facilities.
- *Phase 4: Housing Consolidation*. Upon completion of Phase 1 to 3, township establishment, ownership registration and house construction will commence. The construction of top structures is determined by individual and community needs, and will be administered through a chosen National Housing Programme, which can include *inter alia* a People's Housing Project, contractor built, rental accommodation and/or individual ownership.

The programme objectives are the promotion of tenure security, enhancement of health and security, and beneficiary empowerment through an inclusionary planning process that directly addresses the socio-economic needs of communities (DHS, 2009b). It furthermore calls for a holistic, area-wide focus to development and structures funding accordingly. As such, Phase 1 to 3 are to be funded by a flexible group or area-wide subsidy and is not based on qualification criteria of individual households (WITS, 2004; Huchzermeyer, 2009). Qualification criteria will only apply during Phase 4, which involves the reversion to a chosen National Housing Programme for housing consolidation. All beneficiaries are thus required to be registered on the National Housing Subsidy Database (DHS, 2009b). The phased in situ upgrading approach is intended to minimise the disruption of fragile community networks to the greatest extent possible as emphasised by the fact that relocations are to be sought only as a last resort (DHS, 2009b).

In line with global trends of an expanded role of local government (Goebel, 2007), the programme mandates municipalities to assume the role of developers. Upgrades should be undertaken as community projects (Pithouse, 2009) since community participation is seen to be essential to the

[8] E.g. Community Halls, necessary to ensure member's participation and assistance (DHS, 2009b:32).

success of any upgrade. Funding is made available for additional capacity for facilitation in this regard. This approach engenders a departure from the supply-side rollouts of the past, towards a flexible, demand-responsive approach in that communities are expected to negotiate with local authorities directly based on their needs and desires (Tomlinson, 2006). Housing Support Services are to be established early on in the project lifecycle, through the erection of community halls, to facilitate these interactions (DHS, 2009).

BNG called for an enhancement of building standards as well as stricter compliance on the behalf of municipalities in order to ensure a higher standard of housing outcome (DoH, 2004). The Technical and General Guidelines of the National Housing Code of 2009 specify the National Norms and Standards for the construction of stand-alone residential dwellings, which apply to all units built through one of the National Housing Programmes (DHS, 2009). These include the National Building Regulations (NBR) (as published in the Government Gazette) which specify building performance standards; all applicable Standards introduced by the NHBRC (e.g. SABS standards); the 'Red Book' (developed by the CSIR) which outlines settlement design and layout principles; as well as all Norms and Standards outlined in the Housing Code itself. Should alternative forms of construction have been applied, then compliance with the NBR's will only be considered if this is in accordance with the Deemed-to-Satisfy rules of SABS 0400, an Agrément SA or MANTAG certificate[9] or a "rational design prepared by a competent person" (DHS, 2009b:23).

The minimum service levels in regards to municipal infrastructure are prescribed and concern water, sanitation, roads, storm water and street lighting. Electricity or an alternative form of energy provision is not specified as a minimum level of service for recipients of subsidised housing provision (DHS, 2009b). In regards to the housing product, the guidelines specify a minimum design of $40m^2$ gross floor area; two bedrooms; a separate bathroom with toilet, shower and wash basin; a combined living area with wash basin; and a ready board electrical installation in townships where electricity is available (DHS, 2009b). In line with BNG's notion of Sustainable Human Settlements, the Technical and General Guidelines outline, at length, a set of 'Environmentally Sound Housing Guidelines' in regards to energy and water. These speak to ecological design features for dwellings in order to capitalise on energy-in-use savings and as well as health benefits to beneficiaries. Sustainable water savings interventions are designed to maximise conservation through water saving devices as well as onsite rainwater harvesting. The sustainability interventions however are phrased in the form of recommendations, "the guideline proposes interventions", and as such are not obligatory under the Housing Code (DHS, 2009b:36).

c) Upgrading Informal Settlements Programme – Reform in Practice?

Despite the progressive nature of the new housing policy, it has enjoyed little traction on the ground (Klug & Vawda, 2009; Pithouse, 2009). The programmes dissemination has been weak and none of the nine provincial governments have piloted the programme in terms of Chapter 13 of the Housing Code, let alone full implementation by 2007/8 as stipulated in BNG (Huchzermeyer, 2010). Only recently have implementation attempts been made under the policy prescripts of BNG, notably

[9] These measure non-conventional design against prescribed performance criteria (DHS, 2009b).

through the pressures, guidance and assistance of civic society organisations. The City of Cape Town is working to upgrade the Hangberg informal settlement in Hout Bay with the Development Action Group; eThekwini municipality intends to upgrade three informal settlements in situ in Durban with Abahlali baseMjondolo (Pithouse, 2009) and most recently, Stellenbosch Municipality has commenced with the upgrade of Langrug with the Community Organisation Resource Center (Keller, 2012). Other cities which profess to be upgrading informal settlements in situ have not applied the funding mechanism as outlined in the Housing Code, opting instead the use the project-linked subsidy based on individual qualification criteria, which results in relocation or disruptive "shack shifting" exercises (Huchzermeyer, 2009:65).

Huchzermeyer (2009) highlights reluctance at the local government level in regards to the programme noting that significant re-skilling and capacity development are required in order to commence with the programme. In an attempt to address this, the Department of Human Settlements has initiated the National Upgrading Support Programme to train officials, professionals and community members on the design and implementation of the programme (NUSP, 2010).

Pithouse (2009) cites a further reason for the lack of programme implementation. The introduction of BNG coincided with a shift in the discourse on dealing with informal settlements towards 'slum clearance', 'eradication' and 'elimination' (Pithouse, 2009:10). This change was taken up quite literally by the Kwa-Zulu Natal Provincial government through the passing of the controversial *Elimination and Prevention of Re-emergence of Slums Bill*, which aligns itself to what Huchzermeyer (2010) calls the direct approach to informal settlements. "Apartheid interventions consisted of eviction, the mandating of municipalities and land owners to institute eviction proceedings, forced relocation to controlled transit camps, active control over informal settlement expansion and criminalisation of land invasions[…]. All of these interventions have since found their way back into practice as well as into proposed and approved legislation…" in spite of having been reversed by the Housing Act of 1997 (Huchzermeyer, 2010:133). These current practices are in direct contrast to the legally enshrined *indirect* approach, which on the one hand seeks to address the structural causes of informality in relation to access to land, services and houses, and on the other hand the effects, through the upgrading informal settlements *in situ* (Huchzermeyer, 2010). Most alarming is the fact that in 2008, the Housing MINMEC (Minister and 9 provincial MECs) instructed other provinces to draw up legislation in line with the KZN Slums Act (Klug & Vawda, 2009; Huchzermeyer, 2010). Indeed, the 'eradication' discourse has had a greater effect on politicians and officials than the innovative and pioneering tenets of the revised housing policy. Tracing the failure to implement BNG, Pithouse (2009) succinctly sums this up as "a progressive policy without progressive politics" (Pithouse, 2009:1).

d) Shortcomings of the UISP

> *"But "upgrading", while a step in the right direction towards more people-centered kinds of urban policies and planning, is often too vague. It can still mean big projects that results in the removals of many shack dwellers to new slums outside of the city to*

> *make way for improvements that often accrue only to a few of the original residents of the area"* – (Bradlow, 2010a:1).

Whilst the UISP addresses some of the shortcomings of the previous housing policy, numerous authors contend that the programme is not without significant shortcomings itself. The first failing regards tenure arrangements. The first 3 programmatic phases are to be implemented in accordance to a new progressive community or area-based subsidy mechanism for land and infrastructure, designed to offer greater implementation flexibility (WITS, 2004). However, housing consolidation in Phase 4 involves the reversion to a chosen National Housing Programme, involving the application of a household-linked capital subsidy[10], which is subject to individual qualification criteria. "The serious problem here is that all the intermediary phases that allow for incremental upgrading are not approved by the State unless they lead to Phase 4" (Bolnick, 2010). This significant aspect of the programme not only appears to be poorly resolved but also contradictory in light of the shift towards area-based subsidies (Huchzermeyer, 2006). Freehold title, as the ultimate form of tenure, is thus perpetuated through the policy in favour of a developer-led approach, resulting in the perpetuation of low-density, RDP-style housing, with concomitantly higher land requirement. Secondly, social relationships, vital to the survival of many slum dwellers, come under significant strain during the upgrading process. The physical movements necessitated by the prescribed in situ upgrade process increase the vulnerability of beneficiaries who are required to relocate to a transit camp and then back to a RDP house over a course of many months or years (Patel, 2009). Besides affecting social relationships, transit camps have the added dimension of placing families under considerable financial stress, in that they dislodge residents from their livelihoods (Cohen, 2009). Thirdly, relocations will remain an inevitable consequence of the UISP, given government's singular focus on formal housing delivery (Bradlow et al., 2011) – the practice of "a house on a fully serviced property with freehold title" (Del Mistro & Hensher, 2009:333). The Cato Crest in situ informal settlement upgrade displaced 15 households for every 20 shacks that were demolished, since only 5 RDP houses could be accommodated in the same space (Patel, 2009). This leads to the fourth drawback of the current policy, namely the prescribed Norms and Standards applicable to all state-delivered low-cost housing. Whilst stringent standards ensure greater structural integrity and reliability, reducing future operation expenditure for engineering services (WITS, 2004), their high level and prescribed nature are too rigid in the context of in situ upgrading (DAG, 2007). The current Norms and Standards can indeed become a straightjacket to an effective response to the housing crisis, in that they imply greater time frames as well as expenditure on professional expertise, building materials, building verification and certification (Carolissen, 2011). Whilst there is a need to ensure the reliable delivery of services and structural safety for occupants, a reasonable compromise is necessary. Lastly, the heavily prescribed nature of the policy may perpetuate a state-driven, top-down development approach, potentially eliminating the inclusionary and participatory intentions of the programme (Klug & Vawda, 2009; Pithouse, 2009). The immense creative energies of informal settlers, a key facet to their survival in the absence of formalised housing supply, are negated through a state-dominated approach (Sanya, 2010; Bradlow et al., 2011). Indeed, whilst the funding

[10] A central component of the national subsidy scheme that characterized the first 10 years of housing delivery (Huchzermeyer, 2006)

stream under the programme allows for creative responses to land rehabilitation, this creativity will be limited to engineering knowhow (Huchzermeyer, 2006).

In its current form, the shortcomings of the UISP lead to the emergence of the following unresolved conflicts for programme implementation: Firstly, a tension exists between a heavily regulated housing mechanism and the flexibility to adapt to the local context and pressing needs (Carolissen, 2011). Through the phased funding approach, municipalities are forced to 'go all the way' to a fully serviced house (in accordance with an unchanged Housing Subsidy Scheme), given the conditional release of funding upon the submission of business plans in this regard. Secondly, a tension exists between minimum standards for poor people and prescribed engineering norms. Although intended to provide an equitable and safe housing outcome, the heavily prescribed norms and standards (implemented by a large team of professionals) fail to reach a sensible trade-off between service level (safety, functionality, durability) and a reasonable standard adequate for a first time homeowner. Del Mistro and Hensher (2009:348) showed econometrically that "with limited budgets, the greatest utility would be gained by implementing the lowest level for the most number of households". These tensions fail to manifest the progressive precepts of BNG and the UISP and fail to bring about a meaningful reduction in the housing backlog. Instead, the UISP, in its current form, stands the chance of perpetuating the fragmentation reminiscent of apartheid socio-spatial engineering, as well as the low density, urban sprawl associated with RDP-style developments.

2.2.4 Energy Poverty and the Urban Spatial Form

Apartheid socio-spatial planning involved the institutionalisation of racial residential segregation through the practice of herding Africans into discrete 'locations' or 'township' on the urban periphery (Wilkinson, 1998). The emergent Apartheid City was a highly racially segregated, spatially fragmented, and socio-economically unequal urban landscape. Yet, the post-apartheid housing policy has failed to reverse this apartheid urban legacy (Huchzermeyer, 2009; Landman & Napier, 2010; Bradlow, et al., 2011). South Africa's cities remain exclusive domains, inaccessible in formal terms, to the large majority of its poorer residents. As will be seen, this urban spatial form is a key contributor towards energy poverty[11] in urban areas (Wolpe & Reddy, 2010).

Pachauri et al. (2004) posit that the relationship between energy and poverty is one of mutual causation. Understanding poverty in purely economic terms for the moment, energy choices are reflected by the level of income of households on the one hand, whilst the use of unsafe, inefficient and unreliable energy sources contributes towards poverty on the other hand. Following this understanding, it may be deduced that any factor that compromises the economic opportunities of individuals, is in effect impacting their energy choices. An adverse economic influence may thus compromise the energy security of households. This in turn leads to a greater inclination for the poor to use fuels that are more harmful to their health and immediate indoor and outdoor living environments.

[11] Energy poverty is explored in depth in Section 2.4. Suffice to say at this stage, that the phenomenon relates to an absence of sufficient choice in accessing safe and reliable energy sources to support economic and human development.

The locating of low-cost housing developments on the urban periphery has significant costs for the poor who have to spend considerable time and money on transportation to access employment and social amenities. The Apartheid City logic was based on the assumption of the unbridled prevalence of cheap, coal-based fuels, thus allowing low-density, racially divided urban sprawl to occur. Indeed, transportation is the highest energy-consuming sector (56%) of the South African economy (Borchers et al., 2008). In the absence of reliable data, the State of South African Cities 2011 Report uses *time taken to travel to work* as a proxy for transportation expenditure (SACN, 2011). As represented in Figure 2.1, a little below 50% of residents in South Africa's three largest metro's spend 30 minutes or more each day to get to work – a journey which naturally has to be repeated at the end of the day.

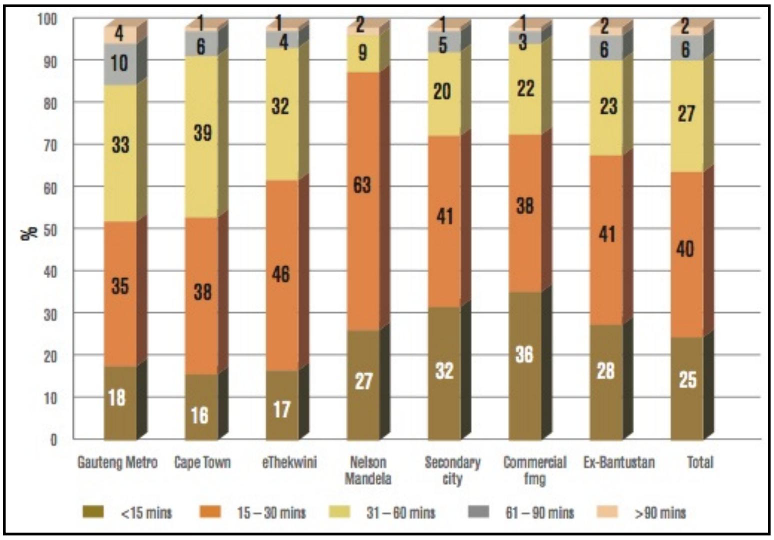

Figure 2.1: Time taken to get to work

Source: South African Cities Network (2011)

Furthermore, extreme urban fragmentation and social inequality makes the provision of services difficult for local governments (Goebel, 2007). The supply of services, based on the prevailing principle of Cost Recovery, is difficult due to the added infrastructure costs resulting from sprawl (Watson, 2009). In terms of urban energy infrastructure, significant progress has been made towards informal settlement electrification through the Integrated National Electrification Plan (discussed in Section 2.3) (Jaglin, 2009) with over 80% of all South African households enjoying a main electrical connection, especially in urban areas (SACN, 2011). Yet despite this and the provision of a starter monthly quantity of Free Basic Electricity, small and frequent additional purchases of electricity need to be made by many poor people, implying a further transportation cost to facilitate this (Ruiters, 2008).

The spatial and economic marginalisation of South Africa's poor urban majority, exacerbated through past and present housing policy and practices thus has a direct contribution towards energy poverty in South Africa's cities. Following, is an analysis of the pro-poor energy policies, which have in part addressed the energy deprivation and poverty of South Africa's poor as a result of, *inter alia*, this dysfunctional urban spatial form.

2.3 Pro-poor Energy Policy and Programmes in South Africa

Post-apartheid energy policy has focused on two primary objectives, namely the satisfaction of the basic needs of its citizens and to promotion of economic growth (Borchers et al., 2008). In light of the focus of this study, programmes and policies that satisfy the former objective will be analysed. The most effective poverty targeting energy policies and programs in post-apartheid South Africa have been the National Electrification Program (NEP), the Free Basic Electricity (FBE) policy as well as the off-grid concessions programme (Prasad & Visage, 2006). Since attention is paid to informal settlements in urban and peri-urban areas in this study, the latter will not be reviewed, since it revolves around the electrification, by means of solar PV, of rural off-grid communities. Instead, the Free Basic Alternative Energy (FBAE) policy, although not nearly as successful as the NEP and FBE initiatives, will be reviewed, since, in theory, it creates the platform for clean energy alternatives for urban and peri-urban off-grid households.

2.3.1 National Electrification Programme

Energy poverty had remained largely off the policy agenda during the apartheid years, given the political marginalisation of the vast majority of South Africans (Bekker et al., 2008). With relaxing apartheid urban influx controls during the 1980s, migration into urban areas drew significant attention to the welfare and energy needs of the urban poor. A business strategy process in the late 1980s revealed the significant socio-economic benefits that could be realised through a mass electrification plan (Gaunt, 2005). To its advantage at the time, South Africa faced few of the barriers typically constraining mass electrification in other developing countries, such as lack of skills, lack of access to capital and supply infrastructure (Bekker et al., 2008). Due to capacity overbuilding in the 1980s, South Africa had a world-class electricity supply industry with a reserve margin of 55%, thus enabling the kind of mass electrification envisaged during the democratic transition (Heun et al., 2010). Bekker et al. (2008) divide the ensuing mass electrification project into three distinct phases:

a) Phase I

The first programmatic electrification stage (Phase I) commenced in 1990 around the same time as South Africa's democratic transition. Dubbed 'Electricity-for-All' (EFA), the programme became a vital part of Eskom's strategy to maintain organisational autonomy in the face of a rapidly changing political landscape (Bekker et al., 2008). Prior to this, Eskom had only connected those households that could afford to pay for the capital cost of connections (DME, 2001) as well as subsidised connections to white rural farmers, motivated on economic grounds (Gaunt, 2005). During the EFA programme the utility gradually expanded access in the recently acquired bankrupt distributors in South Africa's former homelands, a move that was financed entirely out of internal company revenues (Bekker et al., 2008). The culmination and resolution of Phase I was the landmark agreement between Eskom and the newly democratic government to address the electrification backlog by providing electrical connections to 2,5 million houses by 1999 (Heun et al., 2010). The EFA programme had managed to connect 418 919 domestic customers (Gaunt, 2005), yet approximately 64% of South Africans still lacked access to grid electricity, a figure comprised mainly of previously disadvantaged and rural populations (DME, 2001).

b) Phase II

The resultant National Electrification Programme (NEP) (Phase II) targeted these low-income households, schools and clinics in both urban and rural areas (DME, 2001). During the 1980's emphasis in the electrical supply industry had been placed on high quality and reliable supply, with connection cost a secondary consideration (Bekker et al., 2008). Drastic budgetary overruns during the NEP substantiated the need for a breakthrough in the *modus operandi* given the ambitious targets set for the NEP (DME, 2001). This gave way to numerous ground breaking innovations in order to meet the cost-optimisation imperative.

Significant research into the consumption characteristics of domestic customers revealed that design loads could be decreased in urban areas from up to 7kVA per household in the 1980s to approximately 1.5kVA in 2003. A change in the specification of the allowable voltage regulation on low-voltage systems, from ±6% to ±10%, implied a reasonable relaxation in terms of the quality of supply. These design innovations implied significant capital investment savings through the installation of 'lighter' electricity infrastructure. Secondly, technological innovations in the form of prepaid metering systems resulted in significant savings since postal billing, meter reading and manual disconnections and reconnections were no longer necessary. The installation of 'readyboards' (a unit comprising the distribution board, plug sockets and light switches, placed in a central dwelling location) reduced the need for further house wiring. Single-phase lines were introduced for small loads, previously supplied from three phase lines, thus reducing the requirement for wiring, phase conductors and bulk structure costs. Lastly, the adoption of computerised management tools, decision-aiding tools and new econometric evaluation methods allowed for improved planning and implementation by Eskom. Knowledge transfer and exchange was encouraged through fora between all stakeholders involved in the electrification process, as was the ongoing training of skilled network designers (Bekker et al., 2008). These trends allowed for drastic reductions in the cost per connection up until the early 2000s, when commodity price pressures and a focus on connecting remote rural areas increased the prices once again (Table 2.1) (Bekker et al., 2008).

Table 2.1: Average cost per connection and annual capital expenditure

	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Average Cost per connection (Rand)	3 400	2 949	3 245	2 356	2 889	2 676	2 586	2 699	2 655
Capital Expenditure (R mil)	1 487	1 411	1 473	1 176	1 234	1 186	1 011	909	899

Source: ESMAP (2007)

The cost of the NEP were once again borne by Eskom which, having exhausted its internal funds, turned to private capital markets through bond issues, as well as a series of cross-subsidies of industrial users and bulk municipal sales in order to fund Phase II (Bekker et al., 2008).

c) Phase III

Whilst a significant number of rural connections had been made in the 1990s, the primary focus up until 2002 had been the electrification of urban areas. Phase III of the programme (from 2000 until today) saw the introduction of an off-grid solar photovoltaic concessionaire programme for remote rural areas as well as free basic electricity for poor households (discussed below) (Bekker et al., 2008). Under the concessionaire programme, households are to be provided with a standard $50W_p$ panel, sufficient to power 3-4 light bulbs, a radio and television (Pereira et al., 2011). Institutional restructuring which saw the Department of Provincial and Local Government being tasked with the provision of basic services, as well as the corporatisation of Eskom into a tax paying entity, meant that Eskom was no longer willing to contribute towards electrification. As such, Phase III is entirely funded out of the fiscus (Bekker et al., 2008).

d) Evaluation of the NEP

The NEP became the world's most successful electrification programme (IEA, 2010). It exceeded original target having electrified 2.7 million households by 1999 (Table 2.2), and increasing the number of domestic customers from 3 million in 1990 to 6.8 million in 2000 (Gaunt, 2008).

Table 2.2: Targeted and achieved electrical connections under the NEP

	1994	1995	1996	1997	1998	1999	Total
Eskom	250 000	300 000	300 000	300 000	300 000	300 000	1 750 000
Other	100 000	100 000	150 000	150 000	150 000	150 000	800 000
Total Target	350 000	400 000	450 000	450 000	450 000	450 000	2 550 000
Achieved	418 918	478 767	453 995	499 391	427 426	443 290	2 669 345

Source: Gaunt (2005)

On the downside however, whilst statistically impressive, the NEP failed to reach its socio-economic objectives given the lack of coordinated integration with other initiatives aimed at improving infrastructure, services and economic development (Visage, 2008). The NEP facilitated access to electricity but many poor households could not afford the new service (DME, 2003a; Prasad & Visagie, 2006; Visagie, 2008). Indeed, further measures were necessary in order to allow newly electrified poor households to enjoy the full benefits of electrification.

2.3.2 Free Basic Electricity

> *"The introduction of FBE was partly in response to the realisation that electrification is not synonymous with a migration by low-income households to electricity"* – (Bekker et al., 2008:3135).

As part of its election manifesto for the 2000 Local Government Elections, the ANC promised a basic level of services to all poor South African households, a contribution towards the 'fight against poverty' (ANC, 2000). Free basic services were to include free water, electricity and other municipal services. The amounts were later quantified as 6000liters of water and 50kWh electricity per household per month (Department of Finance (2003) in Ruiters, 2008).

The 50kWh monthly provision to targeted households was deemed sufficient, since research at the time showed that 56% of grid-connected households consumed less than 50kWh per month, and comprised a vast portion of South Africa's poor population (DME, 2003a). The 50kWh level was considered adequate for "lighting, media access and limited water heating and basic ironing (or basic cooking) for a poor household", and "ha[d] been spoken of generally at national level and ha[d] been accepted as a norm" (DME, 2003a:9). For customers not connected to the grid, 80% of the monthly subsidy amount was to be provided for non-grid systems, such as Solar Home Systems (DME, 2003a). The Free Basic Electricity (FBE) policy component was promulgated in 2002 and only effectively introduced by local governments, tasked with its implementation, in 2004 (Bekker et al., 2008).

The FBE policy guidelines stipulate a set of options designed to aid implementing authorities in targeting beneficiaries, setting tariffs and deciding on the level of service to be provided (DME, 2003b). Targeting the beneficiaries can be through a broad-based (or blanket) approach, or the alternative, cabinet approved, self-targeting approach, which placed the onus on households to lodge applications themselves (DME, 2003b). The self-targeting approach can take one of two forms:

- *Without current-limiting* – households with consumption below the pre-determined amount of 150kWh per month are placed on a special non-current limiting tariff and receive the first 50kWh free. Typically for urban households with higher demand patterns, this prevents frequent supply trips.
- *With current-limiting* – connections are restricted to typically a 10Amp supply. Premised on the fact that the poor generally have a low demand for electricity, this method provides beneficiaries with electricity up to 50kWh at no cost, after which an approved tariff applies (DME, 2003a).

The policy furthermore allows for three different tariff structures to be applied. These could take the form of a fixed monthly rate, inclining block tariff or single energy rate tariff, irrespective of consumption (DME, 2003b).

a) Benefits of FBE

Proponents of FBE might point out that FBE has made significant impact to the energy usage patterns of the poor. A study in Khayelitsha found that after the introduction of FBE, 53% of Serviced Shacks and 68% of RDP Houses reported an increase in the consumption of electricity (Cowan & Mohlakoana, 2005). Assuming a constant total quantity of energy consumed, this would imply a reduction in traditional fuel usage.

b) Shortcomings of FBE

Significant criticism of the FBE policy abounds, specifically in regards to the 50kWh amount, the practice of current limiting as well as the insistence on the installation of Prepaid Meters in order to access the subsidy. Whilst the policy has improved the affordability of electricity for certain households, it has failed to reach those in greatest need – the poorest of the poor – who remain unelectrified (Borchers et al., 2008; Visage, 2008). Firstly, numerous authors point out that the 50kWh allocation is insufficient, especially for the most energy intensive activities such as cooking and water/space heating (Ruiters, 2008; Adam, 2010), resulting in continued use of traditional fuels in unsafe appliances. When presented with a meagre supply of energy, the poor are often forced to rationalise this for their highest benefit (Villagran, 2000). Simulating the energy demand of a poor household's most essential energy services (excluding entertainment, communication and cleaning) demonstrates that the FBE allocation only caters for between 14% and 19% of a typical low-income household's energy needs, depending on the season (Table 2.3) (Adam, 2010). Secondly, the practice of current limiting by insisting on the installation of 20Amp supplies increases the incidence of electrical tripping. At this level, a maximum load of 4.5kW can be placed on the line making the concurrent usage of numerous appliances such as a kettle, cooking and lighting impossible[12] (Adam, 2010). Thirdly, the installation of prepaid meters is a requirement for FBE to be delivered (Adam, 2010), a fact that warrants further analysis, since prepaid metering has some unavoidably severe consequences for indigent households.

Table 2.3: Essential energy services and their energy demand

Energy Services	Avg Power (kW)	Nr Devices	Avg Hours Operation (summer)	Avg Hours Operation (winter)	Daily kWh (summer)	Daily kWh (winter)
Space Heating	0.75	1	0.00	5.0	0.0	3.8
Lighting	0.02	3	6.0	8.0	0.4	0.5
Hot water (kettle)	3.00	1	0.5	0.5	1.5	1.5
Cooking	2.00	1	1.0	1.0	2.0	2.0
Warm Water (washing)	3.00	1	1.0	1.0	3.0	3.0
Refrigeration	0.15	1	12.0	8.0	1.8	1.2

Source: Adam (2010)

c) FBE and Prepaid Meters

In order to access FBE, indigent households are required to install prepaid metering technology. Undeniably, prepaid meters have numerous benefits, which the World Bank's Energy Sector Management Assistance Programme (ESMAP) (2007) lists as follows: (1) Manual meter readings are no longer required; (2) Billing becomes redundant; (3) No more overdue accounts or bad debts; (4) Makes budgeting of energy consumption easier; (5) No customers complaints regarding bills; (6) No more dependence on potentially inefficient postal service; (7) Transparent and equally applied automatic disconnections; and (8) Job creation at vending stations (ESMAP, 2007). What is apparent is that most of these benefits accrue to electricity suppliers. Indeed, the prepaid metering 'hardware' has numerous drawbacks itself, however, if combined with the policy 'software' such as FBE (as required by the policy), a devastating result emerges for many poor households.

The erratic and irregular income stream of poor households does not allow them to purchase large amounts of credit in advance. In the likely event of the FBE allocation running out during the month[13], electricity credits are purchased frequently and in small amounts, resulting in repeated

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[12] There is evidence to suggest that the insistence on current limiting is being reversed. From June 2011, Stellenbosch Municipality for example provides the standard 60Amp line to all its residents regardless of Indigent status.

[13] A survey showed that the average consumption in Khayelitsha was 150kWh/month (Jaglin, 2008).

trips to electricity vendors. Consumers often have to commute – incurring additional transportation costs as well as an increased exposure to the risk of muggings. If repeat purchases are not imminently possible, households may loose additional money if the food in their fridges starts to rot (Ruiters, 2008).

Research conducted in Khayelitsha found that residents chose to 'skip a week', a decision which implied the reversion to primary fuels such as paraffin, as a means of replacing electricity (Annecke (2005) in Ruiters 2008). This practice is evidence of 'energy deprivation', the reduction of the consumption of electricity below a level for health and comfort, and should be distinguished from 'energy efficiency', which is the conscious endeavour to save money without infringing on human quality of life (Annecke & Endelli, 2006).

"All [that] prepaid meters do, is force poor households to consume less by cutting themselves off. So, rather than the city having to go in and cut off […] for non-payment, the city lets the technology do it for them. They simply distance themselves from the 'structural violence' of cost recovery", analyst David McDonald was quoted as saying in *Metroburger* (Ruiters, 2008:258). Eskom's promulgation of prepayment technology was a key facet of the success of its Electricity for All program which was intended to be run on a business basis, that is, the costs were to be recovered from the users (for an analysis of the objectives behind the development of the technology – see Appendix B) (Van Heusden, 2008). Initially, connections were calculated to break even at a monthly consumption level of 537kWh (at a fixed tariff), a level which was higher than most households were using, resulting in the pernicious act of providing some households with appliance 'starter packs'[14], a practice that was intended to induce consumption (Thorne, 1995).

Prepaid meters were imposed on people as a means to solving the technical problem that emerged out of the political imperative of the time for 'corrective action' by placating the masses through gradual provision of electricity through the Electricity for All program (Van Heusden, 2008). "PPMs [Prepaid Meters] have thus become more than a simple technical answer to disconnection and their present diffusion transcends the social and spatial inequalities" (Jaglin, 2008:1903). The systems have primarily benefited supply authorities, whilst contributing towards poverty at the household level. Through the insistence on their promulgation, insufficient FBE allocation and expensive subsequent tariffs, poor households inevitably remain multiple fuel users. In conclusion, Ruiters (2008) sums up the main arguments against FBE, and places them within a political context:

> *"FBE, at one level, is about the state caring for the people's welfare; at another level, it may be understood as a way to isolate and manage the 'problem' of mass poverty in South Africa. One key aim of the state is to fight a perceived 'culture of non- payment' for services and promote more acceptable market behaviours amongst its citizens. Administrative techniques and engineering technologies (such as prepayment smart cards) have thus been developed for demarcating users as indigents and limiting access.*

[14] Typically including an iron, kettle and two-plate stove, a strategy which Thorne rather tactfully sums up as "not necessarily imply[ing] least-cost household energy planning" (1995:32).

> *The poor are forced to accept sub-standard services (like the 10 ampere (amp) supply, which trips when several appliances are used simultaneously) in exchange for a small amount of FBE. Rather than uplifting the poor, the onerous means of access and the punitive, self-targeted pre-restriction (the 10 amp service) represent a cynical attempt to manage this sector of society, rather than provide genuine and adequate relief from poverty and social exclusion."* – (Ruiters, 2008:249).

2.3.3 Free Basic Alternative Energy Policy

Government realised that it was unable to reach its policy goal of 100% electrification and, as such, would fall short of its constitutional mandate of providing free basic electricity services to all South Africans (Wolpe & Reddy, 2010). In 2007, a policy was formulated to address this shortcoming, by providing indigent households, either un-electrified or uneconomically distanced from the grid, with Free Basic Alternative Energy (FBAE). The objective of the policy is to:

- Provide free basic alternative energy to unelectrified indigent households;
- address a suite of socio-economic issues that arise from inadequate provision of energy (where possible);
- minimise healthy risks by promoting safer fuels;
- promote safe, sustainable and easy accessibility of energy carriers; and
- maximise efficient use of energy carriers (DME, 2007).

The policy outlines a non-exhaustive list of energy carriers, which includes coal, paraffin, LPG and bio-ethanol gel. In order to advance the safe application of the fuels, municipalities are required to conduct awareness campaigns outlining the safe storage, handling and use of fuels (DME, 2007). Municipalities are tasked with the implementation of the policy by identifying areas where energy poverty is prevalent; that are most distant from the grid; and where there are no immediate plans for electrification or a solar home system program. Indigent households qualify for a minimum amount of R55/month of energy according to their FBAE allowance – a figure which is to be adjusted by inflation plus 1,5% on an annual basis. The program is to be financed through the Equitable Shares grant allocation and disbursed by the Department of Cooperative Governance and Traditional Affairs (COGTA) (provincial government) to municipalities for the provision of free basic services, but municipalities are encouraged to provide supplementary funding from their own budgets (DME, 2007).

a) Progress on FBAE

Although well intended, the policy has gained little traction at the local government level. According to Wolpe and Reddy (2010) although there have been attempts, there is no successful municipal implementation anywhere in South Africa yet (Wolpe & Reddy, 2010). Tshwane metro ran a pilot project which failed (Maboda, personal communication). Statistics South Africa however, reports the following delivery statistics for 2009, based on its *Non-financial census of Municipalities* (Table 2.4).

Table 2.4: Number indigent households with FBAE

Province	Coal		LPG		Paraffin		Candles		SHS		Fire Gel		Other	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Western Cape	0	0	0	0	0	0	0	0	0	1530	0	0	0	0
Eastern Cape	0	0	0	0	44619	73464	0	0	3597	4115	986	1214	0	0
Northern Cape	0	24	0	0	638	968	422	401	0	0	0	0	428	401
F State	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KZN	0	0	0	1586	1100	0	0	0	13478	14271	25155	29649	0	0
N West	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gauteng	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mpumalanga	0	0	0	0	0	0	0	0	2900	3100	3600	4135	0	0
Limpopo	0	0	0	0	0	0	1995	1995	5549	5251	540	2185	0	0
South Africa	0	24	0	1586	46357	74432	2417	2396	25524	28270	30281	37183	528	401

Source: Statistics South Africa (2007)

It is difficult to account for the discrepancy, and indeed Maboda states that COGTA has a long list of implementing municipalities. However, when approaching these, none of these could confirm any projects or programmes of implementation (Maboda, personal communication). Either way, in all likelihood, the figures reported by Stats SA may be for municipal energy initiatives which fall outside of the FBAE ambit, and certainly do not reflect any significant clean or renewable energy interventions under the policy.

The lack of adoption of FBAE appears to lie with financial and institutional bottlenecks. Municipalities are expected to fund free basic service provision from the Local Government Equitable Share allocation – an unconditional annual grant. There is thus no ringfenced financial allocation for FBAE provided by the National Treasury. Since a rollout of the policy implies significant administrative capacity and logistical support, this would become an additional financial burden to municipalities already providing other free basic services at a loss (Wolpe & Reddy, 2010). Moreover, municipalities lack the skills to identify appropriate alternative energy sources to meet the needs of poor households (SANERI, 2008). Indeed, it is the lack of capacity to co-ordinate activities and support implementation that is one of the primary inhibitors from an institutional perspective (SANERI, 2008; Wolpe & Reddy, 2010). Municipalities are constitutionally mandated to reticulate electricity and gas but not alternative energy, and as such consider it their constitutional responsibility to provide FBE but not FBAE. The City of Cape Town for example has prioritised electrification over other forms of energy provision, even in the face of a growing informal sector[15] (Wolpe & Reddy, 2010). At the community level, those that do qualify for FBAE may not be aware of it, whilst others fear that acceptance of FBAE may preclude them from being electrified in the future (SANERI, 2008; Visage, 2008).

2.3.4 Discussion

The NEP facilitated broad access to electricity, FBE improved the affordability of the service (albeit insufficiently), and FBAE has failed to benefit those that remain unelectrified. These trends are reflected in the most recent national energy consumption statistics in the 2007 Community Survey

[15] The city does plan to run a pilot project, the results of which are to be shared with other municipalities if successful (Wolpe & Reddy, 2010). The project has however not materialized as yet, due to *inter alia*, funding constraints (Wolpe, personal communication).

as reported by Statistics South Africa[16] (Table 2.5). By far the highest proportion of South Africans use electricity as the primary source of energy. Yet, fuelwood, paraffin and candles still make up a significant portion of the energy baskets of remaining households. This implies that millions of people are still exposed to these primary fuels.

Table 2.5: Fuel type for Primary Energy Services in South African households in 2007

	Electricity	Gas	Paraffin	Wood	Coal	Dung	Solar	Other	Candles
Cooking	66,39%	2,01%	14,80%	15,24%	1,20%	0,25%	0,03%	0,08%	0,00%
Heating	58,69%	1,02%	13,04%	20,21%	3,92%	0,21%	0,07%	2,84%	0,00%
Lighting	80,08%	0,17%	5,27%	0,00%	0,00%	0,00%	0,24%	0,54%	13,71%

Source: Statistics South Africa (2007)

The discussion above has established the fact that the human settlements and pro-poor energy policies have a direct effect on the energy poverty levels of South Africa's poor. In order to understand energy poverty better, attention will now be turned to literature on this phenomenon.

2.4 Exploring the relationship between Energy and Poverty

2.4.1 Energy and Poverty

One of the primary distinguishing features about the world's poor is their lack of access to modern, clean energy sources. Globally, 2.5 billion people meet their primary energy needs through the consumption of biomass (TERI, 2008) and 1.6 billion people still do not have access to electricity (UNDP, 2007). The World Health Organisation (WHO) reports 2.5 million deaths per year due to indoor air pollution – the emission of particulate and smoke matter due to inefficient combustion of fuel (WHO, 2009).

Understanding the nature and dynamics of poverty is important if one is to assess the way in which energy affects it. Poverty is a multi-dimensional issue affecting human life and goes beyond the narrow conception of the absence of income (Silva & Nakata, 2009; UN-DESA, 2010; Bhide & Monroy, 2011). At its most fundamental level, poverty may be thought of as deprivation "in terms of [the] constraints [it places] on people's choices to access certain material goods, assets, capabilities, freedoms and opportunities" (Pachauri et al., 2004:2084). It describes a "…condition of people that are denied the opportunities for a tolerable life" (Bhutto & Karim, 2007:58). Invariably, 'a tolerable' life is open for subjective interpretation. However, it is common understanding that a life of poverty implies the denial of the most basic human needs of access to shelter, water, health care, education and transportation (Bhutto & Karim, 2007). While energy is not a basic need in itself, it is the means by which the most basic of human needs can be satisfied (Silva & Nakata, 2009). Its transformative power in lessening the burden of poverty (Batliwala & Reddy, 2003) has been recognised by intergovernmental bodies and development agencies alike (Vera & Langlois, 2007).

The United Nations, through the Millennium Development Goals (MDG), has "provide[d] concrete, time-bound objectives for dramatically reducing extreme poverty in its many dimensions by 2015 –

[16] The most up to date data will only be available in late 2012, after the Census 2011.

income poverty, hunger, disease, exclusion, and lack of infrastructure and shelter – while promoting gender equality, education, health, and environmental sustainability" (UNDP, 2005:7). The MDGs do not explicitly mention energy as a quantifiable target, however, it is acknowledged that energy is an essential ingredient in achieving all of the MDGs (Silva & Nakata, 2009).

Scholars refer to the concept of 'energy poverty' when describing the interrelationship of the two terms. It appears however that there is no hermeneutic consensus on the precise meaning thereof. Silva and Nakata (2009) describe it as "the condition where people cannot afford access to a sustainable energy supply" (Silva & Nakata, 2009:3097). For Barnes et al. (2011:894) energy poverty is "the point at which people use the bare minimum energy (derived from all sources) needed to sustain life". The authors review different approaches to measuring energy poverty, all centered on quantifiable thresholds such as per-capita annual quantity of energy or energy expenditure as a proportion of household income. The latter approach is called 'fuel poverty' by Sefton and Chessire (2005), who regard it as "households which require 10% or more of their income to attain WHO standards" in order to maintain ambient indoor climate (in Liddell & Morris, 2010:2988). For the purposes of this study, the reductionist focus on quantifiable metrics in defining 'energy poverty' will be avoided. Instead, the UNDPs (2000) definition will be applied, namely "the absence of sufficient choice in accessing adequate, affordable, reliable, quality, safe and environmentally benign energy sources to support economic and human development" in defining energy poverty (in TERI, 2008:2).

2.4.2 Debunking Myths: Characteristics of Poor People's Energy Use

As a way of describing the energy use characteristics of poor people, it may be useful to debunk four of the most prominent myths by providing evidence to the contrary.

Myth 1: Since Biomass energy is free, people using this form of energy are insensitive to price changes (Saghir, 2004).

Biomass energy in the form of woodfuel (fuelwood and charcoal), dung and crop residues, may arguably be collected free of charge in woodlands, forests or vacant fields, yet the opportunity cost of forgoing employment in an alternative productive enterprise attributes a monetary value to this energy source (Adeoti et al., 2001; Saghir, 2004; Pachauri et al., 2004). For women and children, the collection of fuelwood is an important aspect of the day, a necessary activity that can take many hours (Price 2000; Bhutto & Karim, 2007). Furthermore, the scarcity of biomass due to deforestation has led to the commercialisation of many biomass sources, especially in peri-urban areas (Townsend, 2000). In Khayelitsha, a peri-urban township outside of Cape Town, a significant informal market for fuelwood has been established, which is used for informal *braais* and sheep head vendors preparing meat on open fires (Nissing & Von Blottnitz, 2010). The collection and trade thereof can thus form a vital source of income for the unemployed. In Malawi, for example, woodfuel is the most important commercially traded fuel, employing an estimated 133 000 full-time people or 2% of the population at a market value of $81 million or 3.5% of GDP (Openshaw, 2010).

Whilst being freely available in areas such as "urban forests, roadside trees, open areas and garden trees" (Openshaw, 2010:371), the commodification of fuelwood has resulted in its price sensitivity to global market forces. In a study into the dynamics of fuelwood cost in Nigeria, it was found that its price was correlated to inflation and fossil fuel energy. The average price of a kilogram of fuelwood increased from 1.67Naira to 3.51Naira between 1999 and 2000 – a period of increasing global commodity prices and inflation (Adeoti et al., 2001). In New Delhi, a city where biomass is commercially traded, households using this form of energy as the primary fuel source spend between Rs360-480 per month, compared to LPG users, who will only spend Rs350-400 per month (TERI, 2008). Clearly, the use of biomass energy by the poor affects them directly through market price movements, as well as indirectly, through the opportunity cost involved in its acquisition and as such – they are thus undoubtedly sensitive to its price movements.

Myth 2: The energy that poor people use is cheaper than the energy used by wealthier households (Saghir, 2004).

The differing efficiencies of energy conversion technologies, such as lamps and stoves, as well as the variations in calorific quantities of fuels has a direct impact on the quantity of fuel that is required for a given energy service. Using inferior energy sources in inefficient appliances (Table 2.6) entails a higher per unit cost of useful energy derived, as depicted in (Table 2.7) (Bhutto & Karim, 2007; Pachauri et al., 2004). To this effect, Kaygusuz (2011) observes that "the cost of useful energy can be quite different from the cost of the primary energy or fuel" (Kaygusuz, 2011:939). Furthermore, primary fuels, such as paraffin and candles, can be purchased in smaller quantities on a more frequent basis to match the often uncertain and irregular income stream of many poor people (Saghir, 2004). As a result the cost benefits of bulk purchases are not realised.

Table 2.6: Typical Energy Conversion Efficiencies of energy sources

Cooking		Lighting	
Energy Source	**Efficiency**	**Energy Source**	**Luminous Efficiency**
Electricity	1.00	Electricity	1.00
Propane	0.77	Candles	0.02
Fuelwood	0.15	Paraffin	0.01

Source: Kaygusuz (2011)

Table 2.7: Gross and Useful Cost of energy sources

Energy Source	Gross Cost ($/kWh)	Cost of useful energy ($/kWh)
Fuelwood	0.01	0.06
Propane	0.05	0.06
Electricity	0.08	0.08
Dry cell batteries	0.59	0.53
Car batteries	2.57	2.31
Kerosene	0.05	5.87
Candles	0.26	13.00

Source: Kaygusuz (2011)

Differences in the design and standards of appliances also have an effect on fuel consumption. A study into the consumption variances of various kerosene-based cooking and lighting appliances reported a fuel consumption range of between 6 to 53 liters/year for an appliance utilisation of 3.5 hours/day (Mills, 2003 in Rehman et al., 2010).

Myth 3: Poor people are unwilling to pay for modern energy services.

Evidence abounds that people in developing countries are willing to pay high prices for reliable energy services, even if the quality of the supply is not always good[17] (Townsend, 2000). Ugandans, for example, spend a staggering $100mil per annum, or 1.5% of GDP, on dry cell batteries to power simple electrical appliances, highlighting the value that poor people place on electrical energy (Townsend, 2000). Through an extensive trust and confidence building initiative in Ahmedabad (India) more than 200 000 slum dwellers voluntarily converted their illegal electricity connections into legal ones[18] (WSP, 2007). In so doing, poor households become paying customers for a service they value highly.

Given the opportunity, poor people are willing to spend a relatively higher amount on cleaner energy services, compared to wealthier households. This is reflected by the fact that poor people generally spend a larger portion of their budgets on energy per se, but also within this expenditure, on clean energy sources, such as electricity (Figure 2.2).

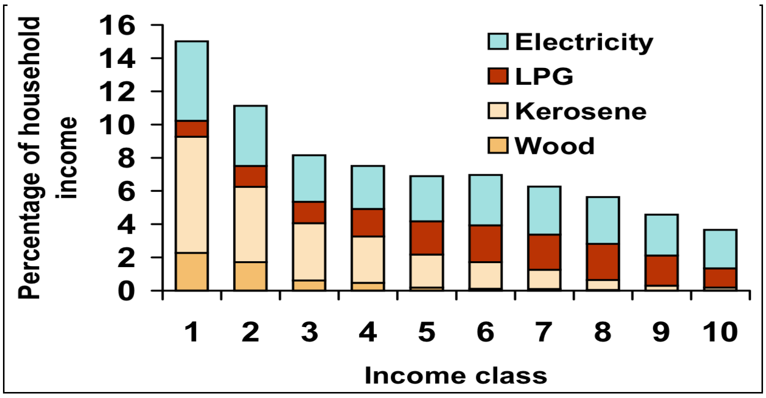


Figure 2.2: Percentage household energy expenditure and fuel mix by income class in Hyderabad (India)

Source: ESMAP (1999) in Saghir (2004)

The reality is that poor people are often precluded from enjoying modern energy services due to insurmountably high access costs (Masera, 2000; Townsend, 2000; Elias & Victor, 2005; Clancy et al., 2008; Karekezi, 2008; TERI, 2008) or due to their sensitivity to price changes, resulting in uncertainty in their ability to afford the service once access has been established (Price, 2000; ERC, 2008; Sovacool, 2011).

Myth 4: The introduction of cheap and easily available modern energy is sufficient to spur socio-economic development (Saghir, 2004).

Generally speaking, rises in income lead to increases in the consumption of energy. These trends may be difficult to observe at the micro level, especially for the poorest households, which may be

[17] Reliability refers to the dispatchability of the energy source, i.e. its availability on demand; whilst quality concerns the inherent quality (e.g. sustainability performance) and service level that that the energy carrier holds. Chemical batteries for example may thus be reliable but of low quality.

[18] Similar examples come from Nigeria and Argentina (see Clancy et al., 2008) and South Africa (see Cowan & Mohlakoana, 2005).

reliant on non-monetary income streams or are reliant on the self-sourcing of fuels (Elias & Victor, 2005). From a macro-economic perspective however, the relationship between energy consumption and income is clearly discernible (Figure 2.3). Indeed, no modern economy has managed to drastically reduce poverty without concomitant increases in energy consumption (Saghir, 2004:3).

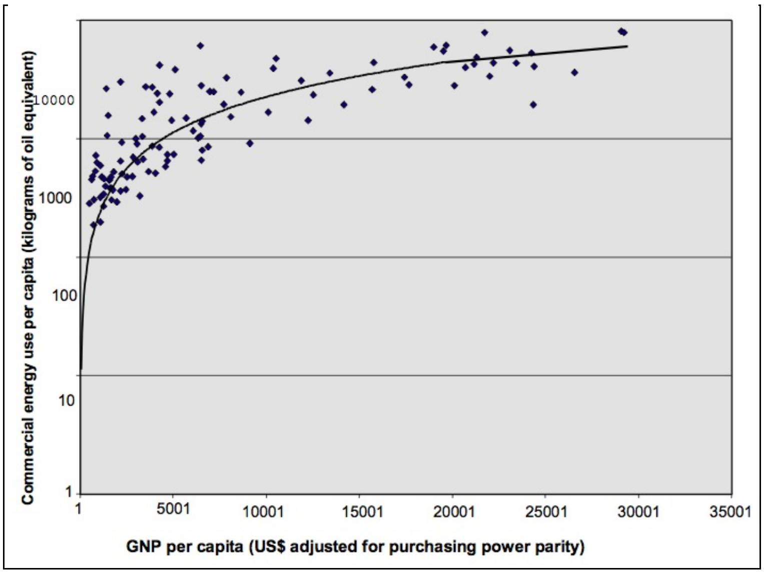


Figure 2.3: Correlation between energy consumption and national income
Source: Saghir (2004)

It is common knowledge that energy is a necessary component to growth. However, increasing access to energy itself is not an automatic stimulant of economic development. Rather it is a necessary, yet insufficient input for development (TERI, 2008). Access to credit, markets, skills training and other resources are essential and complementary inputs that are required for economic benefits to be realised (IEA, 2010).

2.4.3 The Nexus between Energy and Poverty

> *"Without access to, and the transition to, affordable forms of clean appropriate energy, many of the world's poor are 'locked into' livelihoods, which are often unnecessarily environmentally damaging, unhealthy and uneconomic"* (Howells et al., 2010:2730).

This quote to a large extends contains within it the core of the nexus between energy and poverty, in that the denial of energy is a contributor and indeed, entrencher of poverty in all its related dimensions. As was seen in Section 2.3, the relationship between energy and poverty is one of mutual causation (Pachauri et al., 2004). On the one hand, higher levels of poverty are reflected in the energy consumption patterns of households – with poorer households relying on a predominance of traditional fuels, burnt in inefficient appliances. On the other hand, the provision of clean and reliable energy sources can be a catalyst for human development, as recognised by many international agencies and development practitioners alike. Following is a review of some of the direct poverty entrenching and alleviating effects that energy has on human wellbeing.

a) Health

The adverse health implications due to inferior energy usage may be attributable to fuel types and appliances that are used. The effect of poor indoor air quality, through the emission of smoke and other particulate matter, is one of the greatest threats to the health of poor people. The combustion of biomass, such as fuelwood, coal, dung and wood residues on inefficient stoves or open fires is a major contributor towards health complications, especially if used in poorly ventilated or confined spaces (Elias & Victor, 2005; Siddiqui et al., 2005; Bhutto & Karim, 2007). The effect of inefficient cooking appliances exacerbates this problem, since they imply longer cooking times. In a study of the eye and respiratory symptoms amongst women in southern Pakistan, Siddiqui et al. (2005) found that wood users were up to 10.1 times more likely to experience eye and nasal congestion, throat-related symptoms and coughs, compared to LPG users. According to the WHO, 21% of lower respiratory infection deaths, 35% chronic obstructive pulmonary deaths and 3% of lung cancer deaths worldwide are a result of indoor smoke from solid fuels, 64% of which occurring in developing countries (WHO, 2009). Indeed, the WHO ranks indoor air pollution as the second largest environmental health risk (after water and sanitation) (Elias & Victor, 2005) contributing towards an estimated 2 million deaths annually (WHO, 2009). Prolonged exposure to ambient airborne emission has also been linked to "tuberculosis, perinatal mortality (stillbirths and deaths in the first week of life), low birth weight, cataracts and other serious health problem" (Elias & Victor, 2005:18). In a review of fuel poverty studies in developed countries, Liddell and Morris (2010) found significant reported correlations between child and adult mental health ailments, adverse family relations, absence from school and decreasing life expectancy as a result of insufficient fuels to keep the ambient environment warm in winter (Liddell & Morris, 2010).

The appliances used by poor people can also have devastating health implications. In South Africa, it is estimated that 46,000 dwelling are razed annually due to fires, many of which as a result of inferiorly designed paraffin stoves and lamps which are prevalent in informal settlements (Peck et al., 2008). Paraffin is purchased in small quantities in non-standardised, clear containers. Children often mistake these storage containers to be cooldrink bottles leading to fatal poisoning. In a study of the poison ingestions at King Mshinyeni Memorial Hospital in Durban, South Africa, 54% of the sampled 426 cases of poisonings were due to paraffin ingestion, two-thirds of which under the age of 2 years (Paulsen, 2010).

Access to modern energy can have direct health benefits for poor communities. The supply of electricity can enable health clinics to refrigerate vaccines, operate medical apparatus and sterilise instruments properly (Saghir, 2004; Bhutto & Karim, 2007; Bhide & Monroy, 2011). Coupled with improved lighting, workers can enjoy medical attention outside of work hours (Obeng & Evers, 2009).

b) Demographics: Sex and Age

The absence of clean, modern energy sources has a disproportionately adverse effect on women and children, who are predominantly responsible for fulfilling household chores that involve energy. Women are tasked with the burden of collecting large loads of firewood, an increasingly scarce commodity in many areas of the world (Saghir, 2004). In a study on the average household energy sources and activities conducted in Pura (India) it was found that 14% of human energy was spent on the collection of fuelwood alone (Batliwala & Reddy, 2003). The collection of firewood in outdoor areas carries with it the risk of bites, stings, allergic reactions and fugal infections (Batliwala & Reddy, 2003; Elias & Victor, 2005). The need for large families (previously required for agricultural labour) to fulfil basic chores, including the collection of firewood, perpetuates poverty in that it traps mothers in the cycle of child-bearing and rearing. In so doing, they forgo the prospect of education or productive enterprise (Batliwala & Reddy, 2003).

The household fuel mix is a matter of personal choice, and as such is influenced by demographic factors that include gender (Bhide & Monroy 2011; Clancy et al., 2008). Oftentimes men decide which appliances to purchase first. Some might "choose televisions to watch soccer and refrigerators to keep their beers cold" (Annecke, 2008:307), as opposed to appliances which would undoubtedly benefit the household most. Since women and children spend the bulk of time at home, it is they that predominantly get affected by the choices that men can easily avoid (by going to work or a bar), such as an insufficient heating or a polluted indoor environment. Furthermore, it is women that have the added emotional stress of not meeting the family's energy needs (Annecke, 2008).

c) Economic opportunities

The opportunity cost of foregone productivity, through the time cost involved in sourcing traditional fuels, is a major expense to poor people (Pachauri et al., 2004). This is time that could be spent either furthering education, leading to more profitable pursuits, or through the creation of small home enterprises. Improved lighting extends the workday, providing the opportunity of increased production output as well as extended trading hours (Obeng & Evers, 2009). Access to energy has the ability to create new income opportunities, to expanding existing activities and to realise cost savings on current practices (Practical Action, 2010).

Furthermore, poverty costs governments money. At the macro-economic scale, improving the economic self-reliance of poor people eases the fiscal burden of subsidised service delivery (Price, 2000; Bhutto & Karim, 2004). Energy service provision in conjunction with pro-poor related policies can help poor people to access the formal economy, turning them into a tax-paying as opposed to welfare-absorbing citizenry. Small and medium enterprises are especially reliant on reliable energy services and are a vital source of employment for the poor (Saghir, 2004; Clancy et al., 2008).

d) Social Cohesion

Schuller (2000) defines social capital as "*networks, norms* and *trust,* and the way these allow agents and institutions to be *more effective in achieving common objectives*" (Schuller, 2000:2, italics original). Such an objective might be survival or lessening the burden of poverty through the employment of mutual and shared livelihood strategies. "The absence of commercially supplied energy in a society, especially electricity, tends to accentuate the existence of social asymmetry in conditions of living" (Kaygusuz, 2011:937). This breakdown of social capital can be remedied through the introduction of modern energy sources, which have the ability to encourage social interactions and wellbeing of communities. The lighting of park places can increase the sense neighbourhood through the creation of safer public spaces (Obeng & Evers, 2009).

Furthermore, networks of trust and affiliation are created through the exchange of fuels. Whilst not the safest fuel (albeit an improvement over biomass), paraffin is a 'social lubricant' in many informal settlements (Mehlwana, 1997:13). The fuel is regarded as a household basic, is shared between households on a frequent basis, and forms the platform for further commodity exchanges (Mehlwana, 1997).

2.5 Discussion

Given the significant housing backlog and the shortcomings of the current housing development paradigm as enshrined in the UISP, as well as the significant budgetary constraints (which emerge as a result of the continuation of RDP-style housing through the UISP programme) (Misselhorn, 2008), a large portion of South Africa's poor will continue to be without the 'adequate shelter' that the Constitution (RSA, 1996) prescribes. Furthermore, without fundamental changes to the country's pro-poor energy policies, the objectives of poverty alleviation and promotion of equality will not be realised.

Experience has shown that the process of delivering fully serviced low-cost housing, given the tight regulatory system, cannot be expedited in under 6 years (Madikizela, 2012). The Western Cape alone has a housing backlog of some 500 000 units in 2012, with only 15 567 top structures having been targeted in the Medium Term Expenditure Framework for delivery in 2012/13 (Madikizela, 2012). *Ceteris Paribus*, at this delivery rate, an entire generation, or 32 years will pass, before those at the bottom of the housing database in the province will receive their house.

Local governments are mandated to provide basic or emergency infrastructure services in accordance to the prevailing needs and conditions of its informal settlement residents. According to the Housing Subsidy Quantum however, these infrastructure measures exclude energy services. Whilst a normative practice has been the installation of electricity into shacks, this is still done within the technology hardware and policy software that contributes towards energy poverty (discussed above). Furthermore, save for the provision of emergency materials under the Emergency Housing Programme, or migrations into Temporary Relocation Areas, no policy sanctioned top structure response currently exists for informal settlers, save for brick and mortar houses on fully serviced stands. The top structure policy options to informality may coarsely be described as an 'All or Nothing' approach when it comes to shelter provision – either a formalised house or nothing at all. The implications hardly require interpretation. Given the significant funding shortages to meet formalised housing delivery, the vast majority of slum dwellers are consigned to living in shacks with, at best, emergency services which often exclude electricity[19].

[19] To illustrate the implications of this point, Stellenbosch Municipality has an estimated housing demand of ± 30 000 (composed of informal settlers and backyarders) and only receives funding for 300 formalised houses annually. This implies a waiting period of around 100 (Carolissen, 2011).

The options for policy or market sanctioned energy poverty reduction is also not promising. For most South Africa's urban and peri-urban households, access to electricity is not the primary problem, but rather the affordability of the service (ERC, 2008). Eskom has embarked on a R450bn build programme to add an additional 17GW of capacity to the South African grid (Creamer, 2011), the cost of which is to be recovered from electricity consumers through increased tariffs. Starting in 2007, the National Energy Regulator (NERSA) has approved drastic tariff increases, with annual increases of 24.8%, 25.8% and 25.9% approved between 2011 and 2013 (NERSA, 2010). Municipalities, which typically cross-subsidise other service delivery through surpluses on electricity revenues were restricted to tariff increases of between 15,3% and 16,3% per annum[20] (SAPA, 2010). With the prevailing increases in electricity cost (far in excess of inflation rates), it is inevitable that poorer electrified households will switch back to more primitive fuels such as paraffin, resulting in vulnerability, energy insecurity and a slide towards greater levels of poverty. Yet, the prices of primitive fuels themselves are on the rise. The price of paraffin has increased drastically by an average of 16.12% per annum between January 2000 (R1,57/liter) and December 2011 (R8,13/liter) (DoE, 2012). Even fuelwood is correlated to inflation and commodity prices, as discussed above. In the face of eroding real incomes, it would thus appear that poor people have little chance of energy poverty alleviation.

2.5.1 Stylised Energy-Shelter Trajectory

In light of these trends there is thus a need to find alternative means by which to tackle energy poverty at the household level through e.g. dwelling improvements and energy infrastructure services responses, in order to bring relief to those whom development will likely bypass for tens of years to come (Misselhorn, 2011). A generic energy infrastructure and shelter development trajectory can provide the necessary oversight in order to identify places where additional interventions are possible.

This stylised Energy-Shelter development trajectory may be considered (Figure 2.4) with the following discrete and progressive development stages: Unelectrified shack to Electrified Shack to Electrified House[21]. The time frames corresponding to these progressive steps varies greatly between settlements and is determined by factors such as tenure security, funding availability and distance from the electricity grid. In light of the discussion above, successive steps along the stylised Energy-Shelter trajectory are not necessarily associated with an improvement in the energy poverty situation of individual households.

[20] NERSA recently recommended capping municipal increases at 13% per annum (Donnelly, 2012).

[21] In reality, there may be other variant stages along this trajectory, such as Unelectrified House (e.g. Victoria Mxenge in Philippi, Cape Town) or leapfrogging, whereby people go from Unelectrified shack to Electrified House (e.g. Witsand in Atlantis, Cape Town). These however would represent outliers from the generic Energy-Shelter trajectory and are not contradictory to the discussion above.

Figure 2.4: Stylised Energy-Shelter Trajectory
Source: Author (2012)

Introducing further upgrading stages along the stylised Energy-Shelter Trajectory in between the existing generic steps however, might meet the dual purpose of a) reducing the energy poverty of households and b) bringing benefit to more people in reduced time frames. It should be noted that this approach requires an expanded notion of energy service delivery, a break from the predominant technocratic paradigm of grid-reticulated electricity, to include any intervention that significantly reduces energy poverty at the household level. The need for an expanded ambit of energy poverty alleviation measures has already been identified by authors such as Borchers et al. (2008), who posit:

> *"A broader suite of energy services beyond conventional fuel supply subsidies, including thermally efficient low cost housing construction support such as ceilings and plaster and hot water (solar water heating), would pursue poverty alleviation aims more productively, while addressing the environmental footprint and national capacity issues associated with growing electricity demand.*" – (Borchers et al., 2008: 571).

Clearly, alternative means of addressing the energy needs of households exist beyond the reductionist focus on energy supply and affordability interventions. Insulating existing dwellings and constructing new dwellings in line with ecological design principles[22] and sustainable energy may be an additional option in addressing energy poverty.

2.5.2 Expanded Energy-Shelter Trajectory

As such, the Energy-Shelter trajectory may be modified to incorporate two additional and intermediary stages which are proposed as a 1) Sustainable Energy + Retrofit upgrade, in between the Unelectrified and Electrified Shack, and a 2) Sustainable Energy & New Dwelling upgrade in between the Electrified Shack and Electrified House (Figure 2.5). 'Sustainable Energy' are energy interventions that may contribute towards improvements in the social, economic and environmental standing of occupants and go beyond the notion of renewable energy, which typically has a primarily environmental focus; 'Retrofit' speaks to thermal comfort and passive energy improvement of dwellings; and 'Dwelling' refers to a material change in dwelling typology between that of a shack and house. These additional interventions will be explored in greater depth in the coming chapters.

[22] Ecological Design is, "any form of design that minimizes environmentally destructive impacts by integrating itself with living processes" (Van der Ryn & Cowan, 1996:18)

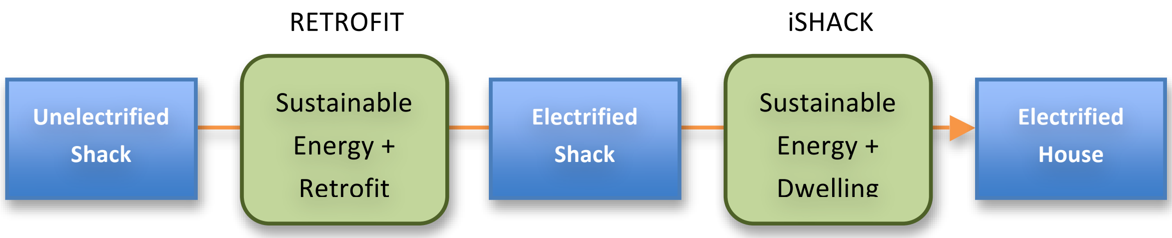


Figure 2.5 Augmented Energy-Shelter Trajectory
Source: Author (2012)

Government's focus on upgrading all informal settlements by 2014 provides the necessary momentum and political will in order to respond with shelter and infrastructure solutions. However, without a reconceptualisation of in situ upgrading, these responses are likely to further entrench structural unemployment and energy poverty for many 'upgraded' citizens. Embedding a clean energy component into an alternative dwelling and energy infrastructure developmental response, in the context of in situ informal settlement upgrading, could lead to progressive, people-centred development and a more sustainable outcome for informal settlers.

2.6 Conclusion

South Africa's revised housing policy, which incorporated a progressive shift in the approach to informal settlement upgrading, has failed to 'break the new ground' as its title envisaged. The housing backlog is on the rise and the proliferation of informal settlements continues unabated. The Upgrading of Informal Settlements Programme, in its current conception, is unlikely to lead to sustainable human settlements. Instead, its highly prescriptive phased process, conditional financing mechanism and insistence on stringent norms and standards implies widespread relocations and the continuation of low density, uniform RDP-style housing developments, albeit (for a select few) on better located land.

The urban sprawl associated with this development paradigm, has a direct impact on the energy choices that poor urban people make, and keeps them in a state of energy poverty, energy insecurity and energy deprivation. Whilst significant progress has been made to increase access to electricity through the National Electrification Programme and to improve the affordability of the service through Free Basic Electricity, many South Africa's poor remain multiple fuel users and as such fail to capture the benefits of modern, reliable and affordable energy services. In the face of rising energy prices, alternative energy interventions, such as renewable energy and energy efficiency, are required in order to cushion the poor from the consequences of these price rises.

A stylised Energy-Shelter Trajectory provides the necessary overview by which to identify additional energy poverty alleviating interventions through the introduction of a combination of sustainable energy and dwelling improvements.

By revisiting the Research Objectives developed in Section 1.4, it is clear that Research Objective 1, (*Determine what the current South African policy and practice is in regards to in situ informal settlement upgrading and pro-poor energy improvements)* and Research Objective 2 (*Investigate* *whether the current human settlements and energy policies affect energy poverty at the informal household level*) have now been addressed. Next, systems knowledge will be generated in order to inform a greater understanding of sustainable energy and incremental shelter options that are currently available.

Chapter Three: Fuel Transitions, Technology Options & Shelter Upgrades

3.1 Introduction

In Chapter 2, the genesis, further development and current implications of the problems associated with the current approach to informal settlement upgrading and energy policies, as they relate to energy poverty, were explored. A stylised Energy-Shelter trajectory assisted in identifying spaces where two additional energy poverty relief interventions could be introduced through a combination of sustainable energy and shelter improvements.

The purpose of this chapter is to generate the systems knowledge necessary to design these additional Energy-Shelter responses. This will be done through a short review of Fuel Transitions theory (Section 3.2), which provides the backdrop against which to assess currently available sustainable energy technology options applicable to upgrading (Section 3.3). From this review, a DC Multigrid solar system is chosen as the most flexible, scalable and appropriate sustainable energy technology for incremental upgrading (Section 3.4).

Systems knowledge on dwelling upgrades is generated through an exploration of prior research and practice in regards to improved informal shelter construction, retrofit insulation materials and plot-reshuffling exercises (Section 3.5). Semi-structured interviews of Enkanini residents reveal the dynamic forces at play in an ever-changing informal built environment and inform an understanding of the thought patterns, values and preferences involved in informal shelter design (Section 3.6).

3.2 Fuel Transitions

The drawbacks of inferior energy sources and their effects on the lives of poor people have been discussed in Chapter 2.4. Clearly, it is in the interest of all people to use safe fuels in reliable and efficient appliances. Indeed, poor people exhibit strong tendencies to replace their traditional fuels with modern ones. Kaygusuz (2011:939) defines an energy transition as "the replacement of traditional sources of energy with commercialised fuels of increasing efficiency…". Two predominant models have been postulated that seek to explain the fuel transitions of the poor, as well as the factors that play a role in their decision-making processes.

3.2.1 Perfect Fuel Switching: Energy Ladder Model

Possibly the earliest theory of energy transitions was a classical model called the 'energy ladder' (Foster, 2000; Rehman et al., 2010) which was developed in the 1980s by Hosier and Dowd (Nissing & Von Blottnitz, 2010). According to this stylised model, biomass (fuelwood and coal) was located at the bottom of the ladder, with Paraffin and LPG at the intermediary stage and electricity at its summit (Figure 3.1). With increases in income, households would transition up the ladder in distinct steps, replacing original fuels with those that offered the benefits of improved health, safety and other related factors. The natural aspiration and objective of the household was to strive to higher rungs on the ladder since these involved the abandonment of prior, more primitive fuels, and associated ill consequences (Saghir, 2004).

The policy instruments that enabled transitions under this hypothesis involved "… subsidies, improvements in the network reliability of modern fuels, better commercialisation schemes for alternative stoves, and other measures" (Masera et al., 2000:2088).

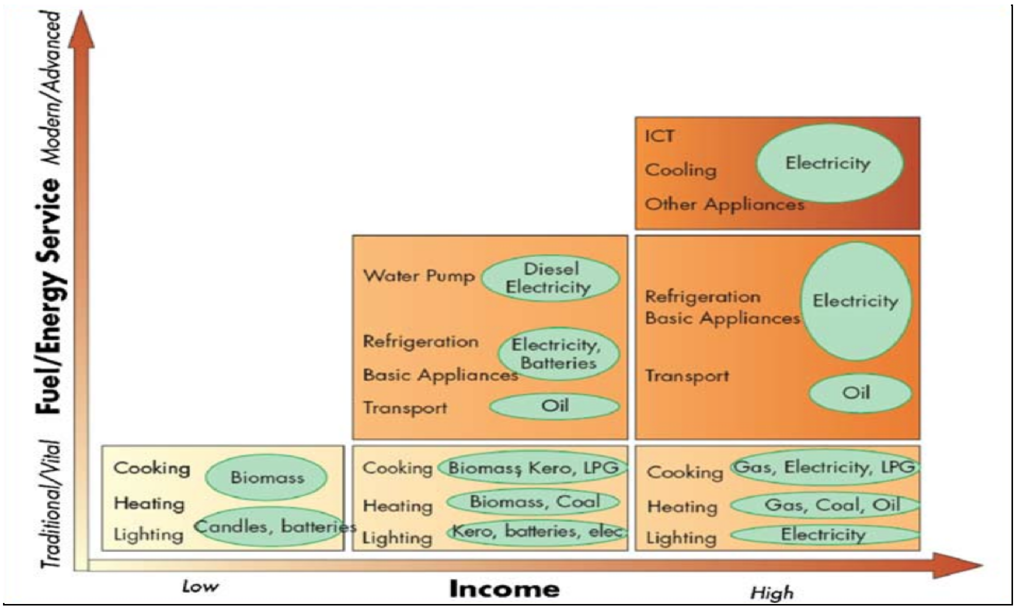


Figure 3.1: Household energy transitions
Source: International Energy Agency in Bhide and Monroy (2011)

The energy ladder theory however has come under severe criticism by academics and development practitioners alike for its overly simplistic interpretation of the way in which fuels are replaced, as well as its overemphasis on income as the sole catalyst and driver of fuel transitions (Kaygusuz, 2011). The model fails to capture the complexity involved in fuel choices, which seemed to be influenced by individual, household, cultural, geographical, climatic and other factors *in addition* to changes in income (Elias & Victor, 2005). Furthermore, the model failed to explain the oft-observed fact that households utilised a range of fuels, even when electrified. The implications thereof, naturally speak to the fact that energy interventions could no longer solely be based on income, but rather that they had to incorporate a blend of previously unappreciated ingredients. Mehlwana (1997:15) showed "…that there are variations between and within places…" and that "…any uniform conception or oversimplified explanation of energy use by poor people is bound to backfire".

3.2.2 Imperfect Fuel Switching: Fuel Stacking Hypothesis

Following the realisation of the inadequacy of the energy ladder model, theorists advanced a new fuel transitions model which captured a more nuanced appreciation of the fuel use and switching patterns of poor people. This included the realisation that fuel switching was imperfect, i.e. it seldom accompanied the complete abandonment of original fuels and appliances. Households tend to keep original fuels and technologies as a form of backup to increase their energy security in the face of rising fuel prices (Elias & Victor, 2005). Furthermore, the capital invested into traditional appliances implies a sunk cost, which will not be recouped during a switch. Households thus tend to hold onto these old appliances, since little value can be derived through their disposal (Elias & Victor, 2005).

These trends have been observed in numerous South African studies. Prasad and Visage (2008) cite four surveys of areas where FBE has been introduced, which reported the continued usage of fuelwood, paraffin and LPG for the most intensive energy usage – cooking. A study in an informal settlement in Grassy Park, Cape Town, found that even though the predominant fuel for cooking and water heating was LPG, households resorted to paraffin and candles for lighting (Wolpe & Reddy, 2010). In a survey of energy use in electrified Khayelitsha, Cowan and Mohlakoana (2005) reported that 33% of sampled households still used more than one cooking appliance and that 24% still used paraffin as the primary fuel for cooking.

Furthermore, fuel switching involves tradeoffs between monetary and time costs that need to be quantified, even in coarse economic terms (Price, 2000). The switch towards a more efficient fuel source may be more costly in monetary terms, but the time saved may make it worthwhile for the household, which can use this more expediently.

3.2.3 Fuel Choice Determinants

Inherent in the fuel-stacking hypothesis is the acknowledgment of a variety of determinants that shape the type of fuels and associated appliances that get used. It is useful to acknowledge these, since they give an insight into the complexity involved in the energy choices made by the poor. Howells et al. (2010) list eight 'circumstantial drivers' that affect fuel choices, namely income, access to appropriate energy, access to undervalued biomass, monetarised trade, institutional intervention, climate and location, household size and cultural preferences. Furthermore, cultural preferences[23] along with availability and affordability (Bhide & Monroy, 2011) cannot be underestimated given the social embeddedness of technology (Pears, 2007; Rehman et al., 2010). Fuel choices are also affected by the natural resource endowments of the area (e.g. coal in Johannesburg) and distance to markets (Elias & Victor, 2005).

Furthermore, many appliances that utilise traditional fuels render more than one energy service (Figure 3.2) as opposed to electrical appliances which are primarily single functional (Mehlwana, 1997). A switch to electricity implies a loss of one or more energy services which would subsequently imply additional fuel expenditure in order to have it met, thus preventing a fuel switch (Louw et al., 2008).

[23] Cultural preference plays an enormous role. In South Africa, there is a common held perception amongst poorer households that LPG is unsafe (Annecke et al., 2008) leading to the avoidance of this fuel. The same aversion to LPG is reported in Jarácuaro (Mexico) given the way it affects the taste of the staple food, tortillas, which are typically prepared with woodfired clay ovens (Masera et al., 2000).

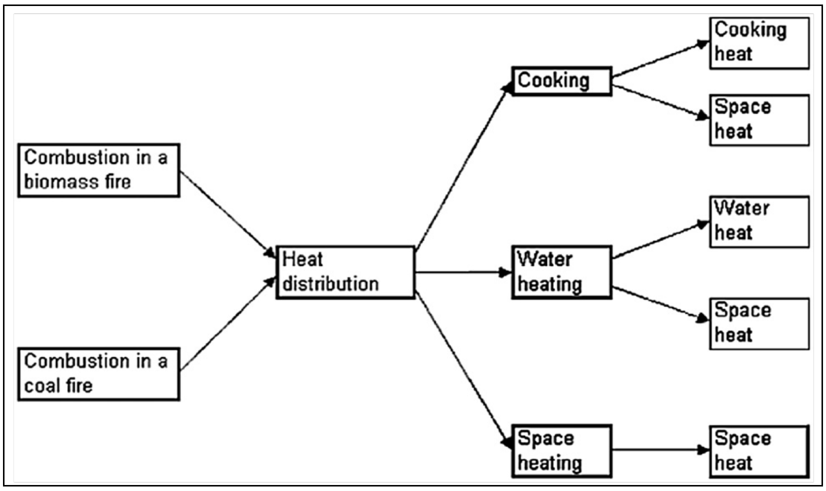


Figure 3.2: Schematic of heating energy service options
Source: Howells et al., (2005) in Sovacool (2011)

Energy interventions need to be nuanced and informed by an appreciation all these complex factors. Given this deepened understanding of household fuel stacking and fuel choice determinants, it is now possible to assess sustainable energy technology options which may be applicable to upgrading.

3.3 Technology Review

The following review is a non-exhaustive analysis of technologies that enable a cleaner fuel switch for cooking, lighting, water heating and multiple-use energy services, and are examined from the perspective of their applicability to shelter upgrades and improved energy switching. The criteria for inclusion in the review were technologies that a) enabled a switch up the generic energy ladder towards cleaner, safer fuels, preferably with perfect fuel switching (i.e. non-fuel stacking) or b) in the event of an existing fuel being used, a technology appliance which leads towards efficiency and emissions improvements[24]. The latter criterion speaks towards the sustainability component of the technology, since efficiency implies 'doing the same with less, or doing more with the same', which has economic and environmental benefits through increased affordability and reduced emissions, in the event of an emitting fuel. Given the bi-directional flow of causation of energy poverty (discussed in Chapter 2), any aspect that improves the economic wellbeing of households can reduce energy poverty, i.e. it has social benefits as well. These criterions informed the ensuing technology review, which is structured according to energy services.

[24] Technology Assessment (TA) is an established field of management study that concerns itself with methods and approaches for technology related decision-making. Inherent to TA techniques is the stipulation of the manner in which selection criteria are designed, a process that directly affects the technology choices. The TA methodological review in Tran and Daim (2008) was consulted to give insight into the methodological options for TA criteria, however the researcher chose his own criteria, since using a TA methodology a) would have been beyond the scope of this study; b) would have distracted from the focus of this work; and c) requires the stipulation of the intended decision making body (governments, business and NGO's) in order to be precise, something that would have had an undue effect on the technology choice in this study.

3.3.1 Cooking

a) Efficient Rocket Stoves

- *Energy Services*: Cooking and Space Heating
- *Models*: 1-Door and 2-Door stoves
- *Producer*: StoveTec (www.stovetech.net)
- *Stockist*: Restio Energy (www.restio.co.za)
- *Cost*: One Door Wood Unit R210 – R260 (volume dependant); Two-door wood & Charcoal Unit R240 – R300 (volume dependant).
- *Description*: The StoveTec stoves are efficient biomass stoves that reduce the need for fuel inputs and resultant emissions through the improved design which includes ceramic interior insulation. The stove functions on all primary fuels, such as grass, corn cobs, animal dung, coconut shells and other biomass fuels, whilst the large mouth to the combustion chamber accommodates irregularly shaped fuel. The stove weighs between 7.6 and 8.6kg, has a diameter of 26cm and stands 29.8cm tall.
- *Features*: Uses 50% less wood & charcoal compared to open fired; cooks 2-4 times quicker with 70% less smoke and 50% less GHG emissions; solid, durable construction; 3 small pieces of wood (30cm x 3cm) sufficient to cook 1.5kg porridge, 1kg rice or 5liters of water in 20 minutes.
- *Applicability to Upgrading*: Whilst still running on primitive fuels such as biomass, this efficient cooker does represent an improvement over the common cooking fuel of paraffin – which has the greatest socio-economic and environmental drawbacks of all fuels. The indoor emission reductions and reduced fuel usage have health and economic benefits, whilst the prevalence of primary fuels makes this stove effective in many locations. The stove furthermore can be used as a space heater as well, since it radiates warmth during and after use.

b) Qala Fuel Briquette

- *Energy Services*: Cooking and Space Heating
- *Models*: Various
- *Producer*: JC Group (www.qalafuel.com)
- *Stockist*: Specialized Solar Systems (www.specializedsolarsystems.co.za)
- *Cost*: Stove cost: R80 (up to R2500 for large applications); Briquette: R2,80 each.

- *Description*: The Qala Stove burns a 450g compressed waste-coal and biomass carbonator briquette that provides users with up to 2 hours of cooking heat up to 800°C, after a 4-minute ignition period.
- *Features*: 86% less CO_2 emissions; cost per hour of cooking is R2.80 – less than paraffin, electricity and gas; left over ash is excellent fertiliser; dry product, safe handling.
- *Applicability to Upgrading*: The cost-effectiveness, indoor emission reduction qualities, the cheap appliance cost and ability to enable dual energy services of cooking and space heating makes the Qala Fuel Briquette a suitable energy upgrade fuel.

c) Sunfire Solar Cookers

- *Energy Services*: Cooking
- *Model*: SunFire 15
- *Producer*: Sunfire Solutions (www.sunfire.co.za)
- *Stockist*: Sunfire Solutions (www.sunfire.co.za)
- *Cost*: R2500 (retail)
- *Description*: The SunFire 15 is a parabolic dish solar cooker which needs to be aligned to the sun every 20-30 minutes in order to gain optimal cooking performance. The power output reaches up to 1000W; can cook a liter of water in 8 minutes.
- *Features*: Self Assembly; the kit weighs 16kg; dimensions: 10 x 72 x 80cm.
- *Applicability to Upgrading*: The SunFire 15 replaces all forms of fossil fuel and even electricity to be powered entirely by sunlight. South Africa has abundant sunlight making this a viable option. Its upgrading potential is hindered by the high access cost (although similar systems can be self-made at a fraction of the price) and inability to provide the cooking service on cloudy days when fuel stacking will be necessary through the reversion to a primitive fuel.

d) Wonderbag Insulated Cooker

- *Energy Services*: Energy efficiency in cooking
- *Models*: Medium (Household) and Large (Catering)
- *Producer*: Natural Balance SA (www.naturalbalancesa.com)
- *Stockist*: Restio Energy (www.restio.co.za)
- *Cost*: Medium R210 – R230 (volume dependant); Large R540 – R570 (volume dependant).
- *Description*: The Wonderbag is an insulated cooker comprised of two poly-cotton bags filled with ecologically harmless expanded polystyrene balls. It safely holds a heated dish while cooking its contents for several hours through heat retention, disallowing any steam to escape during the slow-cook process.
- *Features*: Reduction in cooking fuel consumption of 30-50%; Reduction in energy used for cooking of ±50%; Annual CO_2 emission reduction of 500kg per unit; Light, mobile and durable.
- *Applicability to Upgrading*: The Wonderbag is flexible since it can be used in conjunction to any cooking fuel and can lend itself to incremental upgrading of underlying fuel sources. The investment cost of this intervention will not become redundant in time (it can still be used with electricity) – enabling significant emissions reductions and cost savings.

3.3.2 Lighting

Solar Light and Cellphone Charger

- *Energy Services*: Lighting and Communication
- *Model*: Firefly 12 Mobile
- *Producer*: Barefoot Solar Lighting (www.barefootpower.com)
- *Stockist*: Restio Energy (www.restio.co.za)

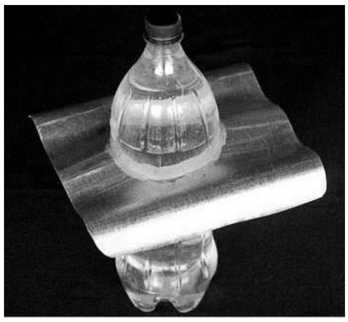
- *Cost*: R195 – R225 (volume dependant)
- *Description*: A turnkey solution that comes in a box, the Firefly 12 assembles in minutes. The unit provides light equivalent to a 15W bulb with sufficient light for 3 children to study at night, or to light up a 3m x 3m room if placed on a wall hook. A mobile phone can be charged concurrent to the light shining.
- *Features*: 12 LED Lamp; Mobile phone charger with 6 adapters; 1.5W solar polycrystalline panel; 4 meter cable; NiCd battery with 2-4 year lifetime; battery overcharge and overdischarge protection; 3 hour charge time on solar or AC power; AC charger; Runtime 4 – 50 hours depending on setting.
- *Applicability to Upgrading*: The appliance holds the promise of fuel leapfrogging, that is, moving directly from primitive fuels to the summit (electricity) through solar charging. Replenishing the fuel stock is done via free solar energy, which eliminates the backward fuel switching threat of reduced affordability – enabling energy autonomy and security. Additionally, the inclusion of a cellphone charger introduces an invaluable energy service with wide ranging socio-economic benefits.

Numerous innovative and cheap lighting solutions have come out of the Third World in recent times. These warrant inclusion since they provide a veritable improvement in energy service level at negligible cost.

Candle of Hope

- *Energy Services*: Lighting
- *Features:* Designed by a Stellenbosch high school science student, the Candle of Hope stabilises a common household candle throughout the burning process through a wire support casing (Stellenbosch University, 2011). Forgotten candles are some of the primary causes of fires in informal settlements, due to the direct exposure of the flame, mixed with molten wax.
- *Required Materials*: Wire for structure; Aluminium Can for base.
- *Cost*: Negligible.
- *Applicability to Upgrading:* Whilst not enabling a fuel switch, the Candle of Hope offers tangible and direct improvements to households through safety at a negligible cost.

Liter of Light



- *Energy Services*: Lighting
- *Features:* Solar Light Bulbs made from empty plastic bottles, installed into the roof of a simple dwelling has the power to provide the equivalent lumens of a 55W light bulb without any connected power source. This simple technology is accessible to all and improves indoor lighting during daytime hours.
- *Required Materials*: PET soda bottle; Zinc roof sheeting; Rubber Sealant; Bleach; Filtered Water
- *Cost*: Negligible

- *Applicability to Upgrading*: The Liter of Light is especially applicable to shacks with few or no windows and in high-density areas. It may introduce the equivalent of electrical lighting for the first time to these dwellings, enabling a range of indoor activities, previously not possible.

3.3.3 Water Heating

Lusty Solar Water Heater

- *Energy Services*: Hot Water
- *Model*: Lusty Solar Water Heater
- *Producer*: Michael Lusty (mwlusty@yahoo.co.uk)
- *Stockist*: Dr Beatrice Wiid (082 441 0190)
- *Cost*: ±R200
- *Description*: Made from food grade poly-ethylene, easily transportable to water source. Users fill up the tank manually, i.e. does not require plumbed installation. Dimensions: 39 x 7 x 59cm.
- *Features*: 10 Liter capacity

Applicability to Upgrading: Immediate programmatic rollout possible with little user training. Can replace existing water canister. Affordable and durable. Can compliment or replace existing water heating technology.

EcoGee Solar Water Heater

- *Energy Services*: Hot Water
- *Model*: EcoGee
- *Producer*: Specialized Solar Systems (www.specializedsolarsystems.co.za)
- *Stockist*: Specialized Solar Systems
- *Cost*: ±R1000
- *Description*: Made from reject evacuated tubes, installed into a steel frame, plastic water tank with an installed tap. Users fill up the tank manually, i.e. does not require plumbed installation. Replacement tubes available at a cost of ±R20each.
- *Features*: 50 Liter capacity; reaches temperatures of up to 70°C; lightweight and easily transportable.
- *Applicability to Upgrading*: Save for cooking, water heating is the second-most energy intensive energy service. Many shacks are strong enough to carry the weight of a grown man (along the support trusses). At ±70kg when filled with water, EcoGee is relatively lightweight and can be installed on the roof of an existing shack. Its independence from monetarised fuel sources ensures no backward fuel switching. Only on instances of low solar irradiation will fuel stacking still occur through the reversion to a primitive fuel for water heating.

3.3.4 Multiple Energy Services

DC Multigrid System

- *Energy Services*: Potential for Lighting, Communications, Cooking, Refrigeration, Entertainment
- *Model*: DC Multigrid System
- *Producer*: Specialized Solar Systems (www.specializedsolarsystems.co.za)
- *Stockist*: Specialized Solar Systems
- *Cost*: Core Unit R3625,20
- *Description*: A main enclosure containing a fused DB Box with five fused circuits; a voltage controller; day/night auto function for energy management; roof mounted solar panel bracket with earthing cap; a photovoltaic cell; fused secure battery box; battery storage; cell phone charger; volt meter indicator; main on/off function and reserve storage capacity to power a pre-paid meter.
- *Features*: Core Unit consists of 3 LED indoor Lights; Cellphone Charger
- *Applicability to Upgrading*: The DC Multigrid system is flexible in that additional energy services such as cooking and refrigeration may be incrementally added to the core unit over time and in accordance with user preferences and budgets. A range of DC appliances are available including radios, hair dryers, televisions, DVD machines, DSTV decoders, microwaves, solar cooking pots, fridges and freezers and motion activated outdoor security lights. These can run off the same core hardware and merely require additional PV panel and battery capacity as required. The system is thus perfectly matched to the energy profiles of user, negating wasteful expenditure. The DC appliances furthermore enable the same level of service as those available to households with conventional AC grid connections. A grid interface module can be installed into the core unit to allow for complete system integration into the AC grid, in the event that the grid arrives. Household energy spend would thus be reduced through the primary consumption of solar energy and the reversion to grid-electricity to supplement shortfalls. The DC Multigrid system enables fuel leapfrogging to electricity, for all energy services, and prevents fuel stacking through the inclusion of three-day system autonomy in the event of reduced solar irradiation. The incremental design of the system ensures that investments never become redundant, even with the introduction of the grid, and households may cumulatively add more appliances.

3.3.5 Technology Choice

According to this technology review, it appears as though the DC Multigrid System is the most applicable for intermediary steps along the Energy-Shelter Trajectory. This is due to the fact that the technology is comprehensive, enabling all energy services (save for space heating) from one core technology. Secondly, the DC Multigrid system permits complete primitive fuel substitution through its built-in system autonomy of 3 days – backward switching to more primitive fuels is highly unlikely. Thirdly, the abundant South African sun is the fuel source, effectively insulating users from price hikes associated with purchasable fuels. And fourthly, no immediate 'in use' emission are generated.

Given the criteria set above and the context of this work, the DC Multigrid System is thus the most appropriate sustainable technology for rapid energy service delivery to informal settlers and will form the foundation of the ensuing research[25]. The system however does not preclude the introduction of other complementary technologies, such as an efficient cooker, LPG cooker or solar water heater, which may still be introduced in tandem to this technology. However, as shall be seen below, the DC Multigrid System is particularly appropriate to the dynamism of slums, especially as it relates to progressive and incremental changes in dwellings.

3.4 DC Multigrid System

A summary of the benefits and drawbacks of the DC Multigrid System sheds further light on the technology's applicability to slum upgrading.

3.4.1 Benefits, Drawbacks and Appliances

The benefits of this technology are:

- Comprehensive approach, one technology can offer all energy services
- Provides an equivalent level of energy service to grid electricity
- Does not require bulk infrastructure services which are costly and take time to install
- Can be implemented independent of government
- Low level of technical sophistication – easy to repair, does not require skilled labour to install
- Low continued affordability cost – solar energy ostensibly is free, no fuel purchases necessary
- Prepayment system options enable revenue collection for implementers
- Scalable and modular – in line with a flexible incrementalist approach
- Prior incremental technological transitions do not become redundant
- Consumers can express their values and preferences through varying technology transitions

The drawbacks of this technology are:

- High access cost presents a hurdle
- Maintenance of systems is essential to ensure system longevity and correct functioning
- Requires user training to ensure correct use of technology, since it cannot be used like grid electricity
- Cloudy weather for more than three days

Using solar energy through DC systems requires a paradigmatic shift in the consumption approach of users in order for the technology to function successfully. From the perspective of the consumer, conventional AC grid electricity ostensibly has no supply limits, yet solar energy, which is decentrally generated and reliant on sunshine, provides only a set number of useable units per day in line with the capacity of the installed system. Consumption thus needs to be rationalised and apportioned to

[25] Formalised dwelling would also benefits through the introduction of this technology as its primary source of energy generation – something that has been tested repeatedly by the technology developer, Specialized Solar Systems (Pty) Ltd., and which is also being introduced at the Lynedoch EcoVillage (Stellenbosch), where two low-cost houses are being built with complete DC Multigrid Systems with AC grid integration.

those energy services that provide users with the highest utility – televisions cannot be left on to provide ambient background entertainment and lights need to be switched off to conserve the charge for when they are needed. To enable these mental calculations, voltage meters are installed for users to keep track of the available 'solar units' (i.e. Watt-hours) that are available for consumption. Basic training is thus essential to educate users on how to optimise consumption and get the greatest enjoyment out of the DC Multigrid system.

3.4.2 DC Appliances and Panels – Ratings and Costs

The DC appliances that are available for use with the DC Multigrid system and solar PV panel sizes, ratings and retails costs (incl VAT) are presented in Table 3.1.

Table 3.1: DC Appliances and PV Panel Cost

Appliance	Description	Rating	Cost
Interior Light	LED with pull switch and 3m cable	3-5W	R74-193
Outdoor Security Light	Motion Sensor with 6m cable	2.4-14W	R336 - 906
FM Radio	AM/FM	2W	R270
Fan	40cm	15W	R595
Hair Dryer	2 speed setting	n/a	R50
Television	16 inch Flatscreen	24W	R1425
	19 inch Flatscreen	35W	R2000
DVD Machine	Plays CDs, USB port	6W	R677
DSTV	Dish, Decoder, Bracket	15W	R699
Bar Fridge	90 liter capacity	28,3W	R4250
Fridge / Freezer	220 liter capacity, Double Door	31,25W	R5900
Chest Freezer	385 liter capacity	31,25W	R8500
Kettle	1 liter capacity	125W	R379
DC Oven	n/a	200W	R1375
DC Slow Cooker	n/a	200W	R1375
DC Microwave	n/a	190-450W	R2000
DC Frying Pan	n/a	165W	R680
Panel Size	**Energy (Wh/day)**	**Cost**	**Cost/Watt**
5W	18Wh	R161	R32,20
10W	36Wh	R321	R32,10
20W	72Wh	R642	R32,05
30W	108Wh	R963	R32,10
40W	144Wh	R1024	R25,60
75W	270Wh	R1920	R25,60
100W	360Wh	R2561	R25,60
140W	504Wh	R2584	R18,45
235W	846Wh	R5415	R23,04

Source: Specialized Solar Systems (2012), adapted by Author (2012)

BOX 2: Tracking the process of innovation towards the creation of a new Solar Home System: A Brief History of the DC Multigrid System from Specialized Solar Systems.

It all started with a lightbulb in 2008. Jonathan Hodgson, a recently retired electrical engineer, designed and assembled a 1.8 Watt LED lightbulb in the workshop of his farm and realised that he had built a lightbulb that was more efficient and affordable than anything else available on the market.

This innovation led him to further design developments in the energy efficiency and renewable energy domain, as well as assuming a fulltime career again as a founding member of Specialized Solar Systems (Pty) Ltd. (SSS). The overriding vision of SSS is to energise Africa's rural communities through appropriate technological and institutional applications. More specifically, SSS set the following objectives to meet their vision, namely to provide a) an equivalent level of energy service to grid electricity at an b) affordable cost to end users with the potential for c) revenue generation by implementers.

The company reasoned that the most viable means to meet these objectives was through the utilisation of off-grid Direct Current (DC) solar energy consumed in DC appliances since this would a) remove the high efficiency losses involved in DC-AC Inversion[26], b) enabling a cheaper product cost, c) resulting in simpler technology that d) could potentially be installed by lay people or unskilled labour.

The team commenced with a process of reverse engineering, that is, looking at a desired result and working backwards to find a practical solution in order to meet their technology objectives, since nothing on the market met their requirements. In doing so, the SSS engineers solved the following challenges:

1. *Taking the danger out of DC* – this was achieved through setting a target high-water mark of a workable voltage range, which would not pose a danger to humans. According to South African electrical standards, unskilled labour may do electrical installations up to a 50 Volt rating. Keeping the systems within this limit allows for wider dispersion and job creation potential.
2. *Developing DC Appliances* – taking high energy users first (air conditioning, lighting, communication etc.) the company, in conjunction with local and international manufacturers, designed DC home and business appliances which only required 25% of the energy that AC appliances needed.
3. *Defining and Refining Efficiencies of Small systems* – the company purchased every available PV panel, battery and controller on the market and tested them over a two-year period. In so doing, controllable inefficiencies were identified and reduced, and optimal combinations of supply equipment were determined for specific system design criteria and applications. This process

[26] Solar PV panels generate DC electricity, which needs to be converted to AC electricity through an inversion process that loses up to 40% of generated electricity, in order to be consumed in AC appliances.

involved designing and manufacturing new components in instances where they were either unavailable on the market, or at an unacceptable level of efficiency.

4. *Designing Recordable Processes* – having perfected the supply and consumption components of the system, the company designed a recordable system which could measure energy input and output, since this was unavailable for their newly designed DC system. This was necessary to refine the products and allow for external measurement and verification by independent parties.
5. *Designing a Prepayment System* – aware that municipalities would never adopt this technology if no revenue stream could be generated (electricity sales account for up to 92% (Hodgson, 2011) of budget for some municipalities), the company designed four different prepayment systems, namely (1) monthly countdown timer, (2) top-up voucher or coupon, (3) key activation and (4) remote GSM controller.
6. *Getting people to understand DC* – the company designed a tailor made training course with easy to understand manuals and teaching techniques in order to train unskilled solar engineers and end users on the technology.

3.4.3 Incremental scaling up of the DC Multigrid System

Scaling up from the initial core unit through the addition of appliances requires supplementary energy generation and storage capacity, brought about by increased PV panel and battery rating respectively. These can be added onto the existing DC Multigrid system, i.e. the core unit remains the same. The formula by which to calculate the cost of an appliance upgrade is as follows:

Appliance Upgrade Cost = Appliance Cost + Panel Cost + Battery Cost

Appliance Cost can be discerned directly from Table 3.1, however additional Panel and Battery cost require calculations based on the anticipated amount of daily energy consumption. This is a function of the number of appliances [‘Qty’], their respective power rating [‘Rating (W)’] and the anticipated usage pattern of the user [‘Daily Use (hrs)’] in Table 3.2, where a figurative appliance upgrade is calculated. The product of these inputs derives the daily energy usage [‘Energy/day(Wh)’], the figure that determines the panel and battery capacity requirements. From Table 3.1, the optimal combination of panel sizes in accordance to the Cost-per-Watt can be discerned to match the calculated energy usage requirement of 321Wh, namely 1 x 75W and 1 x 20W, providing 342Wh of energy per day (assuming 6hrs of sunlight and 40% efficiency loss) at a cost of <u>R3386</u>. The additional 21Wh per day may be consumed by the user as he/she sees fit. In order to calculate battery cost, the storage requirement (in Amps) needs to be calculated. Given that the system functions on 12V, the daily energy usage [‘Energy/day(Wh)’] is divided by 12 to derive storage requirement and subsequently multiplied by 3.3 to build in a contingency reserve in the event of bad weather (of 3.3 days, a convention used by SSS) and furthermore by R10, since this is the average cost per Amp. In the figurative example, the additional battery cost is calculated as 321Wh / 12Volts x 3.3 x R10 = <u>R882,75</u>. The appliances cost (2 x R74) + R1425 + R677 + R680 = <u>R2930</u>. Thus the total cost of the upgrade would be R2930 + R3386 + R882,75 = <u>R7198,75</u>.

Table 3.2: Calculating a figurative appliance upgrade

Appliance	Qty	Rating (W)	Daily Use (hrs)	Energy/day (Wh)
Lights	2	3W	4	24Wh
Television (16”)	1	24W	5	120Wh
DVD Player	1	6W	2	12Wh
DC Frying Pan	1	165W	1	165Wh
			TOTAL ADDITIONAL ENERGY	**321Wh**

Source: Author (2012)

3.4.4 Discussion

Critics of the DC Multigrid System might argue that the technology is too expensive for low-income consumers who will eventually be connected to the grid. This one-dimensional viewpoint fails to acknowledge numerous factors which, put together, can conspire to radically reduce the access cost of this energy infrastructure. Firstly, many informal settlers have cumulatively purchased AC appliances in the hope of being ready when the grid arrives. These can be sold and the funds recouped and invested into DC appliances. Secondly, technology upgrades become feasible over time and in line with the incomes and savings of users, something that the DC Multigrid enables, i.e. it does not force a prescribed upgrade at a static point in time which would render it expensive. Thirdly, the price of solar technology is continually decreasing. Fourthly, the prices quoted above exclude economies of scale, which would be unlocked if interventions were conducted at a programmatic scale. Lastly, subsidies (see Section 6.2) and other financing options (see Section 6.4) that are available for poor people may be unlocked to enable the introduction of the DC Multigrid system.

This then answer the sustainable energy aspect of Research Objective 2 (*Explore alternative sustainable energy and in situ upgrading shelter improvement responses that may simultaneously be energy poverty alleviators*). The DC Multigrid system is an alternative energy delivery response that is more sustainable to the conventional grid electricity, prepaid meters and free basic electricity approach to informal settlement energisation. Reduced in-use emissions, insulation from fuel price pressures, the ability to serve all energy needs (save for space heating) and the ability to match household incomes are core ingredients that make this technology an energy poverty alleviator. The latter part of this chapter will deal with the systems knowledge generation as it pertains to the shelter improvements aspect of Research Objective 2.

3.5 Prior Work and Field Experiences

Learning from the experiences of prior attempts at improved incremental shelter design was the second focal point in generating the systems knowledge necessary to conceptualise additional energy-shelter responses. Most notably, there was an interest in learning about the ecological dwelling design and insulation materials that other researchers had experimented with.

3.5.1 Ecological Design interventions

Developers of new urban settlements hold the key to vastly reducing the energy-in-use requirements of dwellings through the incorporation of ecological design and sustainable energy interventions. These however cannot be introduced as an afterthought and need to be factored into the design of these settlements from conception, since fundamental aspects such as plot layouts, spacing and orientation, which yield the greatest passive energy benefits, cannot be changed later. Few formalised low cost housing developments have been built in line with this approach (DHS, 2010), in spite of the National Housing Code of 2009 specifying a set of 'Environmentally Sound Housing Guidelines' in its Technical and General Guidelines (DHS, 2009b). Fortunately however, precedents for ecologically sound low-cost housing do exist such as the Witsand low-cost housing development.

The Witsand in situ informal settlement upgrade, located on the fringe of Atlantis (Cape Town), utilised the IEEECO™ (Integrated Energy, Environment, Empowerment Cost Optimisation) methodology (developed by the project manager Peer Africa (Pty) Ltd.) in order to improve the thermal performance and energy efficiency of dwellings. This revolved around the incorporation of certain sustainability features into the design of RDP-style, free standing and semi-detached houses in order to capitalise on passive energy interventions. Structural interventions designed to maximise the passive solar heating potential of buildings included correct building orientation, site layout, dwelling layouts, roof overhangs, window placement and the insulation of ceilings and walls. Energy efficient lighting and solar water heaters were installed to reduce the energy-in-use requirements (Figure 3.3) (Guy et al., 2008). Measurement and verification of IEEECO™ units revealed that the units were 5°C warmer in winter and similarly 5°C cooler in summer over outside temperatures[27] (Guy et al., 2008). In comparison to a standard shack, the daily temperature ranges over a 24-hour period for an IEEECO™ unit was 9°C, compared to the 28°C of a shack (Guy et al., 2008).

Project developers might argue that ecological design interventions are more costly, an assertion that is oftentimes true. The Sustainable Housing Calculator however clearly demonstrates the long-term benefits of sustainable building interventions in economic terms, notwithstanding the social and environmental benefits (see Burger et al., 2010). Financing options are required to bridge the higher development costs of energy efficient and thermal comfort building, something that will briefly be examined in Section 6.4.1.

[27] The precise magnitude of these numbers arouse scepticism, however these were reported alongside ticker tape images of data recordings in Guy et al. (2008).


Figure 3.3: Witsand IEEECO™ semi-detached (left) and double story low cost housing units (right)
Source: Photographs by Author (2012)

3.5.2 Fire Resistance through Materials

People's Environmental Planning (PEP) is a Cape Town based NGO conducting research into affordable housing solutions for the "poorest of the poor" (Cuff, 2007), guided by the maxim that a "reasonable structure now is better than a permanent brick home in 5 or 10 years time" (PEP, n.d.). A semi-structured interview was conducted with PEP founder and CEO, Shawn Cuff where he discussed the work that PEP had done in the sphere of emergency housing in the event of disaster relief or temporary relocations during a housing project. The emphasis of PEP's research pivoted on the design of modular units, easily transportable and quick to erect, providing a safe (fire resistance, water, rodent proof) and comfortable environment for occupants.

PEP (2007) had conducted numerous tests involving improved shelter design using concrete cement roof sheets as the primary exterior material. Requiring no timber for structural support (due to the corrugated nature of the panels) the fire resistant qualities of the improved shelter were enhanced, as evidenced by a burn-test where the said structure was compared against a conventional shack (see Figure 3.4).


Figure 3.4: Conventional shack after burning for 8 minutes (left) versus Fibre Concrete structure after burning for 47 minutes (right)
Source: People's Environmental Planning (2007)

The discussions with Cuff (2011) highlighted the importance of considering fire resistance as a central facet of improved shelter design. Furthermore, PEP's work provided a benchmark for the cost of an enhanced fire resistant dwelling, which was $600 for a 15m^2 dwelling in 2007.

3.5.3 Blocking-Out: Improved Shelter and Layout

The Community Organisation Resource Center organised a study visit for the ISUG researchers to provide them with an insight into their current upgrading activities in the informal settlements of Sheffield Road and Joe Slovo (Cape Town) where blocking-out exercises had successfully been completed. Blocking-out involves a participatory planning process in the redesigning of the layout of a cluster of shacks in order to open up shared public space, improve living conditions and open up to the possibility for infrastructure provision. These exercises address the drawbacks of haphazard shack layouts, which are reduced public space, and increased risk of fires, flooding and crime (Figure 3.5). Through community contributions, which are matched on a 1:10 basis by a supporting institution, existing dwellings are demolished and reconstructed in accordance with the new spatial configuration and notably with improved materials. iKhayalami, the NGO providing technical support for these activities, chose IBR roof sheeting for the construction of walls, since the strength and durability of the material allowed them to eliminate the use of a timber frame.

Figure 3.5: Sheffield Road – Creation of public space through blocking out (left) and municipal installation toilets into opened up lanes (right)
Source: Photographs by Author (2012)

3.5.4 Insulation Materials

The Environmental Evaluation Unit (EEU) at UCT conducted a material performance study with an attempt at developing a DIY Home Insulation Kit with the ability to enhance the thermal performance of affordable housing. A multidisciplinary team of material scientists, architects and environmental professionals evaluated 9 different prototypes against a baseline insulation material of Gypsumboard (6,4mm) with 'Isotherm' polyester blanket insulation. Divided into three broad categories, namely Biomass, Plastics and Waste/Recycled Materials, these prototypes were Acacia Saligna wood (Port Jackson) heat and pressure bonded; Acacia Cyclops wood (Rooikrans) heat and pressure bonded; Acacia Cyclops (Rooikrans) wood with acrylic binder (TI-bond), heat and pressure bonded; Recycled, granulated Plastic slab; Cardboard box with Tetrapak; Cardboard box with Sanitary pads; Cardboard box with Eggboxes; Cardboard box with Shredded paper and a Plastic slab with fibreglass sheeting (EEU, 2004). The prototypes were subjected to a set of tests, designed to evaluate the performance against a selection of 15 weighted sustainability criteria[28] (EEU, 2004).

The study concluded that all prototypes had the potential of being viable and sustainable insulation materials, albeit with various strengths and weaknesses. Upon closer analysis of test results a decision was made on the cardboard box with tetrapak prototype since a) it had the best overall thermal performance of all prototypes, b) it was composed of high recycled material content, c) it had excellent liquid water resistance properties after the application of a moisture resistant coating, d) it had relatively low signs of creep (amount of sagging of the ceiling after 14 days), e) no mould was present after a 14 day humidity test, and f) it presented a relatively low amount of embodied energy compared to other options. On the subject of fire resistance – the EEU had designed an ecologically friendly fire retardant paint in association with EnviroTouch Paints. The product's main ingredient is Boron (a chemical element), which has the added benefit of protecting materials from insects and rodents. Furthermore, cardboard and tetrapak are waste materials, which could easily be collected in informal settlements, adding to a reduced cost component.

Through the research into alternative shack construction and insulation materials it was clear that there was significant scope that these components could be combined optimally into a new type of sustainable dwelling as well as partially applied to a prior Energy-Shelter step through retrofit installations. To complement this knowledge, the perceptions of shack occupants was sought in order to shed light on material choice and shelter design processes.

3.5.5 Semi-structured Interviews in Enkanini

The researcher carried out semi-structured interviews of Enkanini community members during the week of 01 August 2011 with the translation assistance of a local resident. Interviews were conducted inside the homes of willing participants who were identified through random house visits. An interview discussion guide was followed, designed to elicit responses that would shed light on decision and design concerns:

1. *Why did you build your shack with these materials?*
2. *Where did you source the materials?*
3. *How much did your shack cost you?*
4. *If you could rebuild your shack what would you do differently?*
5. *What are the good parts about your shack?*
6. *What are the bad parts about your shack?*
7. *If you had R100 to improve your shack, what would you do first?*
8. *If you had R500 to improve your shack, what would you do first?*

[28] The sustainability criteria were thermal resistance, cost, percentage recycled content, renewable/non-renewable material, visual appearance, moisture resistance, fire resistance, weight, mechanical performance, ease of installation, embodied energy, low technological requirement, indoor air quality, pollution from manufacture and durability/lifespan (EEU, 2004).

In total, five households participated in semi-structured interviews, where ample time was given to follow the deliberations and stories that people naturally were inclined to share. This gave the researcher an insight into the adaptive measures that people would take to counteract the difficulties of living informally. The salient details of these engagements, as they pertained to systems knowledge, were as follows:

- The choice of materials was directly informed by their availability at the local landfill site, where all participants sourced their materials. All shacks were made from zinc, plastic sheets and/or scrap wood.
- Zinc appeared to be the construction material of choice (as opposed to wood) given its inherent waterproof nature, reduced fire hazard properties, and the fact that it did not need to be varnished regularly. One participant mentioned the fact that wood expands and contracts with the daytime temperatures, compromising the ability to keep the dwelling airtight.
- The average cost of a shack was the transportation cost from the landfill site, a distance of 5km. This can range from R0 if households carry materials themselves and up to R250 for larger loads.
- The respondents generally felt that, in the absence of the availability of improved materials, they wouldn't have changed anything had they been given the chance to construct again. Only one respondent felt that she would have changed the layout.
- Two respondents felt that a positive feature of their shacks was the way it looked from the outside (these two shacks had been painted recently). Another mentioned the roof, which had recently been replaced. Unanimous agreement was voiced in regards to the drawbacks, which were cited as being wind and water permeability and structural defects due to poor materials.
- Given the option of spending R100 on an aspect of home improvement, all participants stated the installation of ceiling board, which is used for ceiling and wall insulation. Other comments included the purchasing of paint to improve the aesthetics.
- Given the option of spending R500 on an aspect of home improvement, most participants indicated the purchase of additional zinc sheets, primarily to improve leaking roof structures. One respondent mentioned the purchase of additional windows and the improvement of the dwelling layout.

Other notable comments about shack construction included:

- The average lifespan of a shack is approximately 5 years. This can be extended through constant repairs and improvements.
- Structural integrity is provided by 4 or more outside poles which people wrap in plastic at the base to prevent rot (although the efficacy of this measure is questionable). In the case of Enkanini, people cut down trees in the Onder Papagaaiberg nature reserve and fashion them into poles, an activity that has contributed to vast deforestation in the area.
- Building with bricks or self-manufactured iziTena (clay / adobe bricks commonly used in the Eastern Cape) is not prevalent given the uncertainty of tenure – these are perceived to be irrecoverable time and monetary expenses.
- All participants mentioned their challenges in keeping their dwellings waterproof, predominantly through the ceiling, but also the floor.

These engagements highlighted the importance that quality materials could play in alleviating the most elementary drawbacks of air and water proofing, as well as improved structural integrity. The value of insulation was noted as well as the aesthetic value that people place on their homes looking respectable from the inside and outside. Also noted was the preference for zinc sheeting over wood and the importance of a proper roof structure.

At this stage Research Objective 3 may be revisited (*Explore alternative sustainable energy and in situ upgrading shelter improvement responses that may simultaneously be energy poverty alleviators*). The systems knowledge has been assessed (current design and material approaches) as it relates to *upgrading shelter improvements responses.* In Chapter 4, this systems knowledge will be used during a TD design process to generate target knowledge, the *energy poverty alleviating* qualities of which will be statistically analysed in Chapter 5.

3.6 Conclusion

The objective of this chapter was to populate systems knowledge to inform an understanding of prior research and practice in regards to improved shelter construction, design and material choices as well as sustainable energy technologies appropriate for additional increments along a stylised energy-shelter trajectory. The systems knowledge was grounded theoretically within the fuel transitions literature (specifically the Fuel Stacking Hypothesis), as well as anecdotally through an elucidation, by way of semi-structured interviews, of the lived experiences of informal householders as they perceive, interact and relate to the shelter they occupy.

An assessment of the sustainable energy technologies revealed the alignment of the DC Multigrid system with an incrementalist upgrading approach. Furthermore, a review of the EEU Insulation Material Performance study highlighted the benefit of fire retardant and moisture resistant cardboard and tetrapak as retrofit insulation material. This systems knowledge can be synthesised to inform target knowledge, that is, to create alternative development responses along the stylised energy-shelter trajectory.

Part B: Target Knowledge

"Target knowledge is about the desired future status. This recognises the pluralism of norms and values that may be present, depending on actors' perceptions of the system, system relations and options for change." – (Hadorn et al. 2008 in Cronin, 2008).

Chapter Four: Alternative Energy-Shelter Responses

4.1 Introduction

The systems knowledge elucidated in Chapter 3 gave the necessary insight into prior empirical work that had been done in the realm of sustainable shelter transitions and technologies that may flexibly be embedded into various energy-shelter stages. The intention for generating target knowledge revolves around the testing of two additional energy-shelter interventions along the stylised energy-shelter trajectory, and validating these interventions through measurement and verification of the thermal performance and thermal comfort performance[29] of the dwellings (Chapter 5). The two additional incremental interventions are defined as a) a Retrofit intervention between the Unelectrified Shack and Electrified Shack and b) an improved dwelling with sustainable energy component (Figure 4.1). These will be called 'Retrofit' and 'iShack' henceforth, the latter standing for 'improved Shack'.

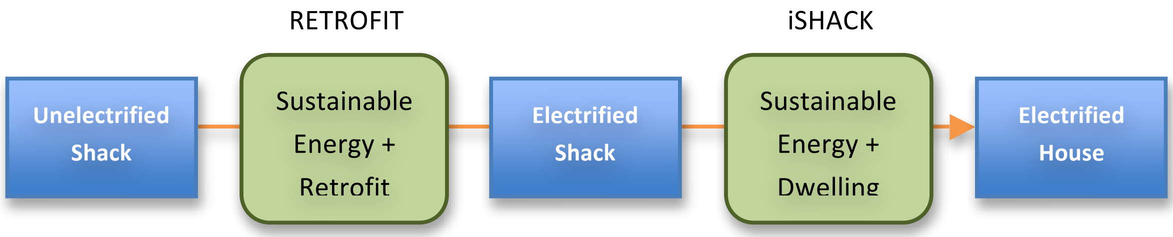


Figure 4.1: Additional Developmental Responses along Energy-Shelter Trajectory
Source: Author (2012)

The Solar Thermal Energy Research Group (STERG) of Stellenbosch University's Engineering Faculty generously offered their Solar Roof as a space to construct the required dwellings and conduct testing. This route would undoubtedly have been more expedient if time and cost were the only variables to optimise, yet would have failed to gain an insight into the situated social factors that ultimately influence the efficacy of a socio-technical intervention. For this reason the target knowledge phase of this study was conducted in Enkanini itself, through the piloting of the Retrofit and iShack (between August and November 2011) with the intention of determining whether a causal link exists between energy-shelter interventions and energy-poverty. To validate this conjecture, an additional shack was needed as a control variable against which measurements of Indoor and Outdoor Temperature, recorded over time, could be compared. This third shack is referred to as the 'Control' shack.

[29] See definition of thermal performance and thermal comfort performance in Chapter 1.

The first part of this chapter is a discussion of the social, legal and administrative, and design processes that converged to give rise to the Retrofit and iShack pilot. Through the social process (Section 4.2) a suitable site and willing pilot participants were identified; the necessary legal and administrative (Section 4.3) terrain was navigated in order for the pilot to be sanctioned by the authorities and; the precise Retrofit and iShack designs emerged out of a transdisciplinary design process (Section 4.4). In the second part of the chapter the specifics of the iShack are discussed as they relate to the design inputs and constraints (Section 4.5.1), the construction process (Section 4.5.2) and costs and quantities (Section 4.5.3), followed by a consideration of the Retrofit shack interventions (Section 4.6.1) and its costs and quantities (Section 4.6.2)

4.2 Social Process

4.2.1 Sampling and Site Selection

The first stage of the social process revolved around the setting of population sampling criteria that would satisfy the research objectives of this part of the study. A set of stringent sampling criteria were necessary in order to conduct this aspect of the research and a purposive sampling strategy was decided on as the most appropriate means in which to identify participating households. This form of sampling relies on the availability of willing participants that are case-representative of the population under examination, and suits the intense social engagements that would inevitably have been necessary to bring results to fruition. Purposive sampling does not produce generalisable results, given the suspension of the statistical principle of randomness (Durrheim & Painter, 2006). This however was not a problem given the objective of this aspect of the study which was not intended to generate precise and predictive statistics of the performance of interventions. The sample criteria by which sites and participants were identified were as follows:

Site Criteria:

a) Three distinct households willing to participate in the research to comprise the iShack, Control and Retrofit households.
b) A piece of vacant land had to be available in order to construct a completely new dwelling (the iShack) and sufficient space available adjacent to the Control and Retrofit shacks in order to make dwelling adjustments to match the iShack size.
c) The three households had to be in close proximity to each other for practical research purposes but also to reduce the climatic variations amongst sites, something that is prevalent in a sheer, contoured terrain such as Enkanini.

Participant Criteria:

a) Household occupants had to be relatively fluent in English to enable communication without the use of a translator, since this was deemed an unnecessary dependency.
b) Households had to have similar occupancy levels, family sizes and user activity given the effect that these factors have on Indoor Temperature in the modest confines of a shack.
c) The Control and Retrofit shacks had to be of similar materials and construction quality.

The process of identifying sites and participants involved spending considerable amount of time simply walking around all parts of Enkanini and having informal discussions with people to discover whether they knew of vacant land. This was done without revealing the fact that a resident was to be the recipient of a new shack, so as not to raise unnecessary complications that could have hampered this study. Fortunately, a fellow ISUG researcher, Joel Bronkowski, was living in Enkanini at the time and found an open patch of land in the 'new arrivals sections' (Figure 4.1), a low-density area on the southern edge of Enkanini where new settlers generally found sufficient space to build their new homes. Madiba Galada, a prominent community leader and the head of a local development committee (no formalised community leadership exists in Enkanini) was consulted in order to assist with determining whether the households in the immediate vicinity were suitable for the intended study. As an outsider, the researcher was aware of potential class, race and language barriers, which meant that local knowledge in the selection of the participants was essential. Criminal elements seek out informal settlements as safe havens to ply their trade and it was necessary to ensure that participants were in fact *bona fide* residents.

The researcher's primary concern was that the Retrofit and iShack participants would be victimised by neighbours. In an environment of abject depravity, it was feared that elevating the living conditions of one household could spur resentment from others. There was also a concern that the neighbourhood densification through the erection of an additional shack would be met with resistance – open space is a valuable commodity in an informal settlement. The researcher was determined to solve these problems by explaining the merits of the project and gaining written consent from neighbours to commence with the study, but was advised against this by Galada. The leader pragmatically noted the difficulty of commencing with the study should permission be withheld and suggested that open communication about project intentions to immediate neighbours would be sufficient to garner support. Furthermore, choosing the resident in the 'worst-off' state to be the iShack beneficiary, would be a convenient way in which to curtail resentment, since this would be a logical step and appeal to the humanity of neighbours. On the subject of open space consumptions, Galada noted the inevitability of further shacks being constructed there in time and that exercising caution with respect to boundaries of neighbouring plots would be sufficient.

Figure 4.2: The vacant land which became the project location (left) and the iShack beneficiary's original shack (right)
Source: Photographs by Author (2012)

Having found a suitable site, the researcher commenced with visiting the area regularly in order to acquaint the people living in its immediate vicinity. To allay initial scepticism about the study's intentions, the assistance of a translator, a local resident called Phulane (an engineering student at Cape Peninsular University of Technology), was sought to assist with introductions and to communicate, in broad terms, that the researcher was interested in learning about current living conditions and how to improve them. After this initial period of engagement, Galada and the researcher commenced with house calls by visiting residents and engaging in informal chatter as a means of eliciting valuable information about the socio-economic standing of households in the chosen area. Galada soon identified the most needy household in the area which had two neighbouring households that fortunately matched the sampling criteria closely. Following are profiles of what turned out to the project participants.

4.2.2 Participant Profiles

iShack household: Nosango Plaatjie

A single mother in her mid 40s with 3 children (one of whom was a stroke victim), Plaatjie was employed once a week as a domestic worker. Her economic standing was compromised by the fact that her husband had relocated to Gauteng and claimed the R750 child grants on a monthly basis. Plaatjie had been a backyarder in neighbouring Kayamandi and could no longer afford the R200 monthly rental. Having moved to Enkanini only 2 month prior to meeting the researcher, her shack was a makeshift structure made from disused pallets, chipboard, plastic sheets and rusty zinc sheets (Figure 4.2). The dwelling had a bare earth floor, was draughty despite having no windows, leaked through the roof and, due to it being adjacent to a waste collection area, had a constant swarm of flies swirling around the room. Plaatjie complained that her children were constantly sick and that rats infiltrated her shack during times of reduced human activity.

Retrofit Shack: Victor Mthelo

A soft-spoken husband and father of two young children, Mthelo's home was located immediately behind that of Plaatjie. A professional painter by trade, Mthelo and his wife, a domestic worker and seasonal labourer employed in the fruit picking industry, took turns working in order to allow somebody to tend to their two young children. The Mthelo family had also relocated from Kayamandi around 2 months earlier. Their home was made entirely out of reused zinc sheets. The Mthelo family's home was constructed entirely out of zinc with one window and a door.

Control Shack: Mthethelele Kohliso

A gregarious bachelor in his early 20's, Kohliso was permanently employed as a barman at an upmarket local restaurant called *Die Wijnhuis*. Kohliso had a girlfriend and son, who lived with her parents in Khayelitsha and who were imminently due to move in with him upon his successful payment towards his *lobola*, which meant that he lived sparingly and parsimoniously in order to complete this monetary instalment. Having previously lived with a brother in neighbouring Kayamandi, Kohliso had settled next door to Plaatjie only a month prior in order to create a new home for his girlfriend and son. Kohliso's shack was made entirely out of zinc – reused sheets as walls and new sheets as a ceiling – with one window and a door. Upon mentioning the intention to build a new shack for Plaatjie, a visibly moved Kohliso was fully supportive – "I will do anything to help this mama". He had heard her child cry that morning, since she had to wash with icy cold water before school since no more paraffin was available to heat water (Keller, 2012).

Communicating with all participants was possible in English, with Kohliso and Mthelo demonstrating notable English reading and writing proficiency as well. The occupancy levels of Plaatjie and Mthelo's households were identical at 4 people, whilst Kohliso expected his girlfriend and son to arrive imminently bringing their households to 3 people, which was acceptable. After the identification of study participants, the researcher sought to obtain authorisation from the requisite authorities in order to commence with the extension of Kohliso and Mthelo's shacks (to match the floor space of Plaatjie's original shack) and the construction of an additional structure – the iShack.

4.3 Legal and Administrative Process

Navigating through the complex terrain of gaining approval for what effectively was an illegal operation, that is, constructing a shack in an illegal settlement, raised numerous uncertainties. Who should permission be requested from? The researcher was hesitant to appeal for unnecessary consent from a party that could utter its disapproval, thus complicating matters. Whilst the iShack project didn't involve the settlement of an additional family in Enkanini, and given the intention of demolishing Plaatjie's existing shack post iShack construction (resulting in no net additional shack in the area) the researcher still felt the need to seek out the approval of numerous agents which might have an interest in, and authority over, the research activities. The Enkanini leadership was approached to sanction the research activities within the community; whilst consent was solicited from the municipality to prevent complications with the land invasion unit. Moreover legal counsel was also sought in regards to the drawing up of agreements to be signed by all implicated parties.

4.3.1 Community Leadership Consent

The researcher encountered many contradictory accounts of the degree to which a local leadership had been established, including numerous reports of ad hoc leadership committees, comprised of representatives from ten districts of Enkanini. What was certain was that, to date, no formal engagement between an elected body of community representatives and Stellenbosch municipality had taken place. The researcher was adamant to get consent from some form of local leadership as reports of punitive measures being taken against households which had contravened an injunction or failed to seek consent from a local leadership committee (when this had been necessary) had been reported. Depending on the severity of the contravention, households were either given a certain timeframe to leave or in more serious cases were immediately, forcefully evicted.

Madiba Galada was the head of one of the local leadership committees and had prominence in the community as one of its founding members. Having involved himself from an early stage of the pilot, during the site and participant reconnaissance, Galada had gained a keen understanding of the merits of the study and had counselled the researcher generously on how to approach the project from a social dimension. The researcher endeavoured to request permission for the commencement of the project from Galada's committee given his prominence as an Enkanini elder; his familiarity with the pilot and his promise to assist Plaatjie and the researcher should any conflict of interest within the community emerge. Unbeknownst to the researcher, the intended area had been earmarked for the construction of a crèche, however the leadership committee gave their blessings for the iShack to be constructed and decided to find an alternative location for the crèche.

Whilst ostensibly no longer necessary, given the endorsement of Galada's committee, approval was requested of Eunice Matshaya – the recently appointed Stellenbosch Civic Association (SCA) councillor – and an influential leader within the community. This was a measure of courtesy but also a prudent measure, since her backing would have been useful in the unanticipated event of social complications. Having successfully obtained permission from the community leadership, attention was turned to municipal authorities.

4.3.2 Municipal Endorsement

The ISUG had numerous successful engagements with the newly established Informal Settlement Unit of Stellenbosch Municipality. A referral was made to Mr Wiseman Ndamase (tasked with registering, authorising and assisting new informal settlers in the municipal area) by David Carolissen, the head of the unit. This was a formality, given that Carolissen was Ndamase's superior, however, the procedure demonstrated the importance of intra-departmental liaising and consultative decision-making processes. Ndamase stated that no project would be sanctioned where the perceived benefit was not apparent, where community members were inconvenienced or where some other conflict of interest was evident. He furthermore specified the need to gain the approval of the local councillor of the Kayamandi Ward 12, which encompasses Enkanini.

Undeniably, new informal settlers did not embark on the same process of 'cutting red tape sideways', yet this process was important in order to prevent the interference and possible demolition of the iShack by the municipal Informal Settlement Land Invasion Unit.

A written proposal was submitted to Ndamase outlining the scope, implications and intended outcomes of the study activities in Enkanini. Following this, the site was visited in order for the official to gain a contextual appreciation of the proposed project. Fortunately, not 3 months prior to this visit, Ndamase had personally granted Plaatjie permission to construct her shack in Enkanini and a visibly warm 'reunion' commenced. Ndamase was pleased to learn that Plaatjie would be provided with improved shelter and that the research outcomes were anticipated to be to the benefit of other informal settlers under his jurisdiction. A meeting was scheduled with the local councillor, Ms Nokuthula Gugushe, who was pleased with the initiative and subsequently gave her approval. This however was subject to her involvement at a formal handover process – an attempt at seising this opportunity for demonstrative political expedience. The researcher insisted on the study remaining an apolitical project given the nature of the research rendering this inappropriate, but more importantly, due to the possible unintended consequences that an unwanted political party affiliation might have had for Plaatjie, in the highly politicised environment of Enkanini. Fortunately, the councillor agreed, again, after a visit to the site, and an intricate elaboration on the intended merits of conducting research of this nature for the people in her ward.

Upon receiving formal recommendations from Ndamase and Gugushe, Carolissen issued written consent and instructed the head of the Informal Settlement Land Invasion Unit to allow the study to commence uninhibited.

4.3.3 Legal Counsel

Reaching a verbal understanding of the intended research activities between the researcher, Plaatjie, Kohliso and Mthelo was relatively easy. However, legal counsel was sought in order to elucidate, in detail, the intention, dynamics, process and intended outcomes of the project and for these to be reduced to simple agreements between the various participants. Johan van der Merwe of Chennels Albertyn Inc., a progressive law firm with offices in Stellenbosch, assisted in this endeavour. It was agreed that the essence of the contracts should be a reference for salient points and that they would not be drafted in a way to be enforceable. Subsequently, van der Merwe drew up agreements, which reflected the contributions of the researcher, the contributions of the householder, the ownership of improvements to dwellings and the ownership of other assets to be installed. Furthermore, the agreements also included details on the intended interventions and impacts to be affected to the dwellings, the nature of technical assistance and support to be provided, as well as a dispute resolution mechanism which involved the mediation by Madiba Galada in the event of a disagreement. Each agreement was tailored according to the nuanced differences applicable to each household, in line with the intended study. As such, Plaatjie's agreement included a technical sketch of the intended layout and design of the iShack, which had been agreed on, and Mthelo's outlined aspects of the retrofit's to be effected.

Given that considerable material benefit would accrue to the research participants, it was important for the participants to contribute their skills according to their capabilities. Plaatjie agreed to cook lunch for the duration of the construction period with comestibles that would be supplied as well as assisting with menial labour according to her abilities, e.g. through the collection of water. Given that her existing shack would be demolished thus rendering materials suitable for reselling, it was agreed that 80% of the proceeds of this sale would go towards purchasing the materials used to construct her new iShack. Mthelo and Kohliso agreed to contribute sweat equity through their help in constructing the iShack. This was in lieu of the materials which they would be supplied with in order to expand their dwellings to match the dimensions of the iShack. The contracts were completed by Chennels Albertyn Inc and Pumlani Sibula, Head of the Xhosa Unit at Stellenbosch University's Language Center, effected Xhosa translations of all agreements.

4.3.4 Participant Agreement

The signing of the contracts was done as follows: All participants met in Plaatjie's shack and everyone had the chance to read through the agreements. Mthelo outlined each point in Xhosa, since it emerged that Plaatjie was unable to read and grasp the entirety of the agreement herself. A lively discussion ensued about all aspects of the project, since never before had all particulars been communicated this succinctly. Issues that required clarification were isolated and discussed in depth with Kohliso and Mthelo offering impromptu translations for Plaatjie. The researcher had decided against using translation assistance for this aspect since a) Mthelo and Kohliso were excellent English and Xhosa speakers, b) the informal and open dynamic between the participants stood at risk of changing through the introduction of an outsider and c) the researcher was set on utilising this engagement to foster a spirit of teamwork. None of the pilot participants raised any concerns about the project particulars, however the aspect of safety evoked a lengthy discussion. Plaatjie feared for the safety of the researcher – that he may be seen as giving handouts and subsequently would be accosted by other community members eager to seek out some benefit for themselves. Upon reflection on this point, it was decided to counteract this potential through limiting construction activities to weekdays, when most people were at work or going about their daily chores. Furthermore, the pilot participants suggested that Galada be present during all times in order to outline unequivocally the precise scope and intentions behind the pilot, and the limitations of the researcher's capacity to effect the same change for others. Furthermore, the researcher was concerned about the possibility of community ostracising of the three participants. All participants however felt that this would not be a problem as long as they 'spoke with a common voice', that is, shared the same story about what was going on in their neighbourhood. Salient aspects of this story were a) the fact that this was 'a project' (a word which apparently had special colloquial currency, implying a once-off initiative); b) that this project was a study, i.e. a test was underway and the outcome was still uncertain; and c) the participants furthermore agreed that they would welcome any reasonable and earnest enquiry from other interested parties and in so doing, would prevent themselves from appearing to be of elevated importance. Having felt satisfied with these approaches, the pilot participants signed both the English and Xhosa agreements, whilst Professor Mark Swilling signed the agreements on behalf of Stellenbosch University[30].

4.4 Design Process

Concurrent to the social and legal/administrative process the design of the iShack and Retrofit shack was in process in order for building to commence without delay upon the completion of all administrative and legal formalities. The methodological approach in identifying actors and disciplines necessary for the Design phase and in line with the 5 key disciplinary foci (Structural

[30] These documents reside with Beatrix Steenkamp, the MPhil course administrator.

Design, Ecological Design, Materials Knowledge, Liveability & Comfort and Thermal Performance) was described in Section 1.8.3. The reader will recall the choice of stakeholder collaboration approach of Rossini and Porter's (1979) *Integration by Leader* Framework for managing knowledge inputs from various stakeholders. A 'bottom-up' design process commenced which took the shape of a series of meetings with pockets of stakeholders where specific design features were discussed, which were informed by a set of constraints and sustainability design criteria (discussed below). The researcher communicated post-meeting roundups from each design iteration by drawing 3-dimensional simulations on Google SketchUp, a sophisticated open source technical drawing package. These simulations became the foundation for further design deliberations. Google SketchUp gave an exact overview of the spatial dimensions which affected aspects such as internal mobility, livability and aesthetics and allowed for accurate but remote design deliberations by various stakeholders. Printouts from SketchUp were used to discuss the various design elements with Plaatjie in order to gain her input. Furthermore, in line with SDI methodology, a cardboard model of the final iShack version was constructed with internal furnishings at a scale of 1:20, which allowed Plaatjie to familiarise herself with the layout and space proportions of the design that had collectively been devised.

4.4.1 Setting the Design Criteria

Design criteria are a necessary means by which to inform and guide any design process. Yet, the researcher was faced with the challenge of selecting criteria for a dwelling for which no objective benchmark was available. A myriad of sustainable design guidelines and rating systems exist, all intended to improve the sustainability performance of buildings[31]. These however are crafted for formalised environments and are unsuitable for the complex contexts of informal settlements, where various other limitations and opportunities for sustainable building exist. The researcher decided to set his own qualitative and quantitative design criteria which were informed by those used in the *DIY Home Insulation Kit Project* (EEU, 2004) as well as his personal in-field experiences, informal discussions and semi-structured interviews. Given the lack of objective comparisons by which to measure the efficacy of the design, the criteria as laid out below, were meant to guide the design approach, highlighting those aspects that would speak to sustainable improvements of thermal comfort. The criteria may thus be simultaneously read as objectives for the design outcome for both the iShack and Retrofit shack designs.

a) Thermal Comfort

Thermal comfort is defined as "a state in which there are no driving impulses to correct the environment by behaviour" (Djongyang et al., 2010:2627), a condition whereby occupants of a building are satisfied with the thermal conditions of their environment. Practically, the objective of achieving indoor thermal comfort is to ensure that the design a) reduces temperature fluctuations and b) keeps the temperature at an acceptable level. This is the first and most important criterion in improving the household energy poverty standing through a dwelling intervention, and all further

[31] Examples of these are a) *Guidelines for Human Settlement Planning and Design* known as '*The Red Book'* produced by the South African Council for Scientific and Industrial Research (CSIR) (Available: http://www.csir.co.za/news/2009/11/red_book.html); b) *The Green Guide to Specification* by British Research Establishment (BRE) (Available: http://www.brebookshop.com/documents/sample_pages_br501.pdf)

design criteria have some bearing on it. The challenge in the context of an unelectrified environment is to design the dwelling in such a way that passive heating or cooling of the dwelling is maximised.

b) Cost

The cost of an Enkanini shack can range between R0 and R5000 depending on whether it is contractor or self-built or whether it was purchased on the vibrant informal real estate market (Figure 4.3). Informal contactors in Enkanini construct basic 3m x 3m zinc shacks with a door and a window for R3000. This cost-per-m^2 of R333/m^2 was used as a benchmark for the cost of the iShack dwelling and an additional R1000 for sustainability interventions was allowed. The rational for this was that the long-term cost savings through initial improved construction costs would be realised through reduced health expenditure and energy costs. Given the intention to replicate the floor space of Plaatjie's original shack of 14,26m^2, this translated into a cost threshold of R5750, which was in line with the inflation adjusted cost of R5811 ($745 at $1:ZAR7.8) of the $600 cost for a 15$m^2$ shack in the PEP study (PEP, 2007).

Figure 4.3: Enkanini shack on the market for R3500 (left) and a new shack being demolished by the Stellenbosch Municipality Land Invasion Unit (right)
Source: Photographs by Author (2012)

c) Design Complexity

In an attempt to speed up construction time and improve the chances of iShack replication in an informal setting, the design complexity had to be reduced through the use of prevalently used construction materials and standardised dimensions, whilst the use of power tools was disallowed.

d) Fire Resistance

High dwelling densities and alcohol abuse coupled with inferior fuels used in inefficient appliances lead to fire hazards within informal settlements. The design had to be such that the prevalence of flammable materials was kept to a minimum. Furthermore, the structural design had to reduce the possibility of the dwelling catching fire from an adjacent structure, as well as the likelihood of an indoor fire escaping and damaging others.

e) Indoor Air Quality

Indoor air quality relates to emissions within an indoor environment, such as volatile off-gas emissions from chemical compounds, as well as other particles such as spores emitted from mouldy surfaces (EEU, 2004). These factors are intensified within the confined space of a shack, obviating the need to remove moisture build-up through proper ventilation over and above the intention to eliminate chemical compounds altogether.

f) Recycled & Renewable Material Content

Notwithstanding the cost benefits of reusing certain materials, it may be argued that shacks are some of the most sustainable dwellings when it comes the percentage of recycled materials from which they are made. Using recycled materials has the added ecological benefit of reducing the carbon footprint of dwellings, whilst the use of renewable over non-renewable content ensures the use of sustainably managed sources (EEU, 2004). Thus, the recycled material content had to be maximised as much as possible.

g) Visual Appeal

The semi-structured interviews and the researcher's personal observations revealed that informal settlers place great emphasis on living in a dwelling that is individualised and visually appealing.

A criterion that is relevant to the discussion of informal settlement shack construction is that of **Construction Time**. A new arrival has to race against time in order to construct his/her shack. Municipal land invasion units are highly organised and may employ a range of tools to counter this, including watchtowers and patrol units on quad-bikes and 4x4's, which dispatch demolition crews to raze new dwellings (Figure 4.3). *Impimpis* (informers) furthermore provide officials with tipoff's of new arrivals. Once a new owner has slept inside the dwelling for one night, it may no longer be destroyed. Construction time was thus initially included as a criterion and set a maximum of 24-hours. However it was decided that this criterion should be disregarded upon the realisation that it would have compromised the 'learning-by-doing' approach, which was necessary to incorporate valuable realisations as and when they emerged, and would probably have led to inferior construction quality.

4.5 The iShack

The iShack design went through ten design iterations over a course of 7 weeks, from 8 August 2011 to 17 September 2011. Following, is a discussion of the constraints which were inputted into the final design as well as specific features as they relate to various aspects of the dwelling.

4.5.1 Design Inputs and Constraints: From the Bottom Up

Keeping the floor space of Plaatjie's original shack of 14,26m^2 (4,6m x 3,1m) constant, the dimensions of the iShack could be altered leaving Plaatjie as well off as before when it came to living space. Exact dimensions of the major pieces of Plaatjie's indoor furniture (2 beds, 2 tables and a fridge) were used in order to simulate a new indoor furniture layout on Google SketchUp in accordance with these side dimensions. In an attempt to use as many materials from Plaatjie's original shack, measurements were taken of Plaatjie's existing door – the only material that was in a satisfactory condition to be reused. A visit to all local suppliers of materials that Enkanini residents typically used enabled the researcher to record the exact cost, quality and dimensions of construction materials[32] in order for these to inform the design process.

4.5.2 Design Features

a) Structure

It was decided that the most suitable material to use for the structural frame of the iShack was wood, given that it could be sourced from an ecologically sustainable source, was cheaper than steel and easier to work with than concrete. The iShack wood was sourced from Somerset Timbers (Pty) Ltd. since they were the only suppliers that had Copper Chrome Arsenate (CCA) treated pine poles in the area – other local suppliers only had creosote coated poles, which are in high demand by wine growers, but have poisonous off-gas emissions. The suppliers gave their assurance that the South African Bureau of Standards accredited CCA treatment is perfectly safe for an indoor environment when it comes to off-gas emissions. An attempt to get moon phase harvested timber poles[33] was unsuccessful, since these were non-standardised items and required a lengthy procurement process with additional costs.

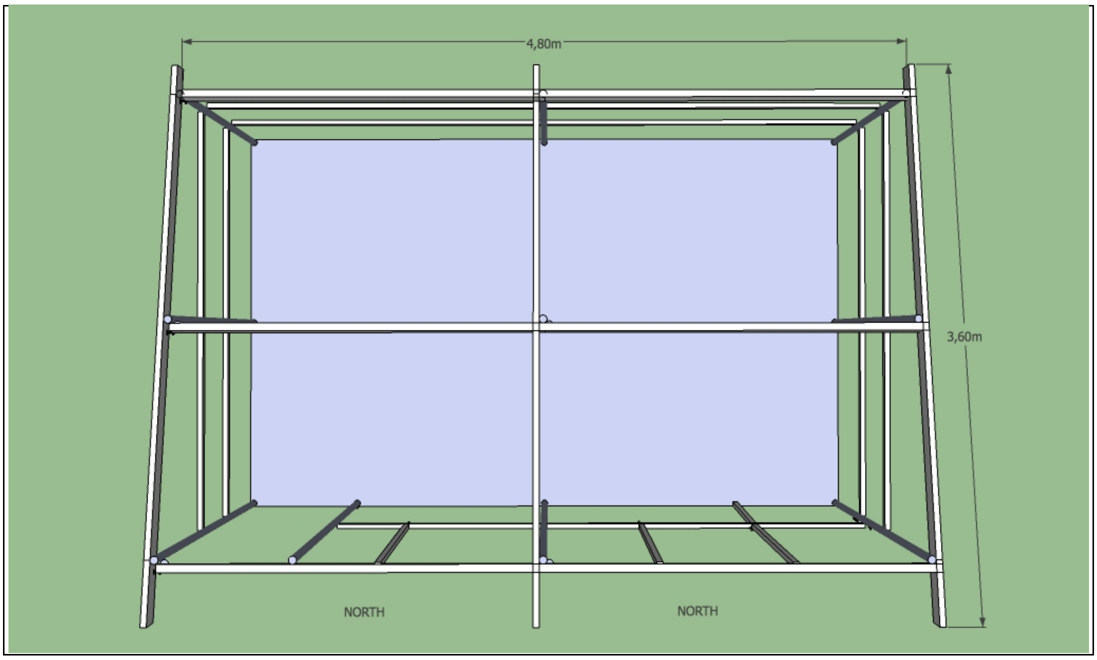


Figure 4.4: iShack structural frame – Top View
Source: Author (2012) on Google SketchUp

[32] These were Builders Trade Depot (1,2km from Enkanini), AgriMark (2,3km from Enkanini) and the local building supplier (in Enkanini itself).

[33] "Moon Phase Harvesting is an ancient method of preserving timber by cutting wood according to the phases of the moon. Like the tides of the ocean, the moon also influences the rise & fall of the sap in the wood. The wood is cut when the sap is lower, which is in the autumn & winter months i.e. hibernation period. During these months the sap in the tree is at its lowest in the days before the new moon. The lack of sap therefore is a natural protection that prevents insects & fungus from infesting the wood & thus increases its durability." (Eco Design Architects, n.d.).

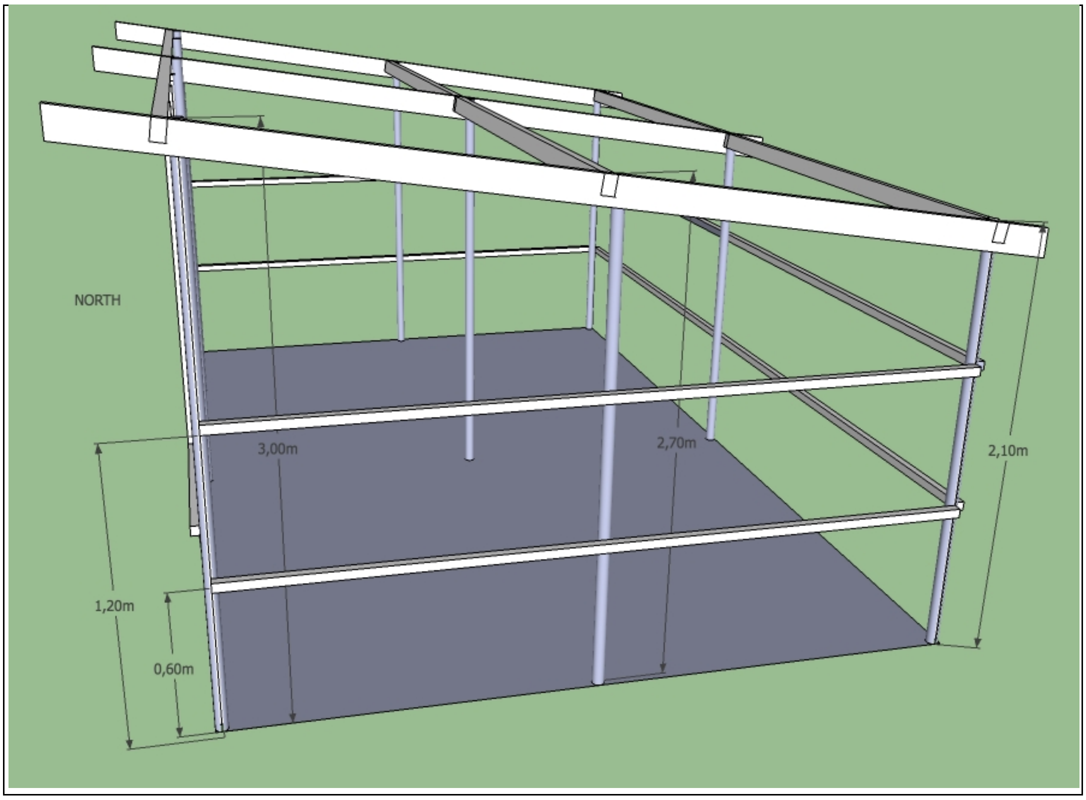


Figure 4.5: iShack structural frame – Western Side view
Source: Author (2012) on Google SketchUp

The iShack frame was designed to have an even weight bearing capacity through the equal and symmetrical distribution of poles, rafters and batons of standardised lengths so that almost no additional mechanical labour would be required in order to make them fit (Figures 4.4 and 4.5). The length of the pine poles was determined by the pitch of the roof as well as the requirement that a minimum of 0,3m additional length was available to fasten the poles into the ground, since no cement was to be used for this function. Rather, a series of large rocks wedged in around the poles and the use of a hand stamper to compact surrounding soil provided sufficient rigidity around the poles. Furthermore, a circumference band of two standard 38x38mm batons, placed at a height of 0,6m and 1,2m above the ground, provided structural stability to the outer poles as well as additional support for the securing of zinc sheets which were nailed into them.

b) Walls

Securing two seams of batons on the exterior of the structure provided an immediate opportunity for the creation of an air gap, an excellent insulator (EEU, 2004), between the zinc outer walls and the insulation sheets on the inner walls. It was decided that a zinc sheet exterior would be the most suitable material to use, given its preference by locals, their knowledge of working with this materials, the prevalence of supply and cost effectiveness in acquisition and maintenance over wood. The walls were designed to prevent water creep, through the digging of small trenches around the perimeter structure and extension of the zinc sheets 20cm or more into the earth (depending on the remaining length of standardised zinc sheet lengths). In line with common practice in informal settlements, the exterior zinc surface was built up by a ramp of earth in order to function as a water runoff. The zinc sheets were designed to bend around the corners in order to seal the structure and prevent air from entering mismatched joints. In order to achieve this – zinc was attached with the undulations running vertically, as opposed to the common horizontal application, having the added benefit of creating a smooth exterior surface at corners and reducing the hazard of sharp edges.

It is common for air gaps to form along the front and rear upper perimeter of shacks, where the undulating zinc roof sheets meet the walls, creating an unwanted draft. Subsequently, the air gaps at the cooler southern end of the iShack were sealed with a mud-lime-straw mixture to arrest a draft from forming; yet the upper north facing gaps were left open in order to allow unwanted warm air to escape.

c) Insulation

Following on from the EEU *DIY Home Insulation Kit study*, it was decided to clad the walls with a layer of cardboard and tetrapak. Initially, it was decided to collect these materials in Enkanini itself, however, in order to expedite the construction of the iShack, cardboard was collected from local retailers and tetrapak was generously donated by Distell Ltd., a large beverage manufacturer. Improving the fire resistant qualities of these materials was of concern, but Bernhard Lembeck, owner of ecologically friendly paint manufacturer EnviroTouch, agreed to prepare the same fire resistant paint which was used in the EEU study, albeit with a modification that allowed the material to be adhered to tetrapak as well. The paint is made from plant oils based on purely natural ingredients, namely a water-based starch/colophony emulsion combined with Borax, a naturally occurring mineral also known as sodium tetraborate. This type of material prevents the easy ignition of cardboard and has a self-extinguishing effect. Lembeck advised the researcher to apply two coats on both sides of the materials and to make sure that the corners were well covered, since these are especially sensitive to catching fire. Common clothing dye, purchased at a chemist, was added to the mixture in order to improve the aesthetics of the cardboard insulation.

d) Ecological Design

Ecological Design is "any form of design that minimises environmentally destructive impacts by integrating itself with living processes" (Van der Ryn & Cowan, 1996:18) such as sunlight and shade, air movements, plants and the inherent thermal properties of certain natural materials. Incorporating these processes into the design of a building can radically enhance the livability of spaces through improved comfort, as well as contribute towards cost savings through reduced energy requirements. Life cycle analysis has shown that reducing the energy-in-use requirements (through e.g. passive design) of a building should be a priority over the choice of construction materials since this will lead to greater energy savings over its lifespan (Roaf et al., 2003). Numerous ecological design principles underpin the iShack design:

1) Orientation – The aspect of the slope on which a building is located and the daytime living areas of the dwelling should be north facing in the southern hemisphere to optimise on passive solar heating and natural light (Government of Australia, n.d.). The front of the iShack however was slightly tilted towards the east, to rest at NNE (22,5°), in order to capitalise on the early morning sunlight, which would warm up the inside through east-facing windows – something that is essential during cold winter mornings[34].

2) Overhang – the eaves of the building should shield against unwanted sunlight in summer, whilst still allowing the lower-angled winter sun in. Coupled with thermal mass and optimal orientation, this is an effective means of smoothing out indoor temperature fluctuations. The Sustainable by Design online database revealed a sun angle of 75,99° at 12h00 on 21 December 2011 – the height of summer. By ensuring that the entire height of the iShack front was shaded during this time, this gave an overhang of 0,59m (Figure 4.6).

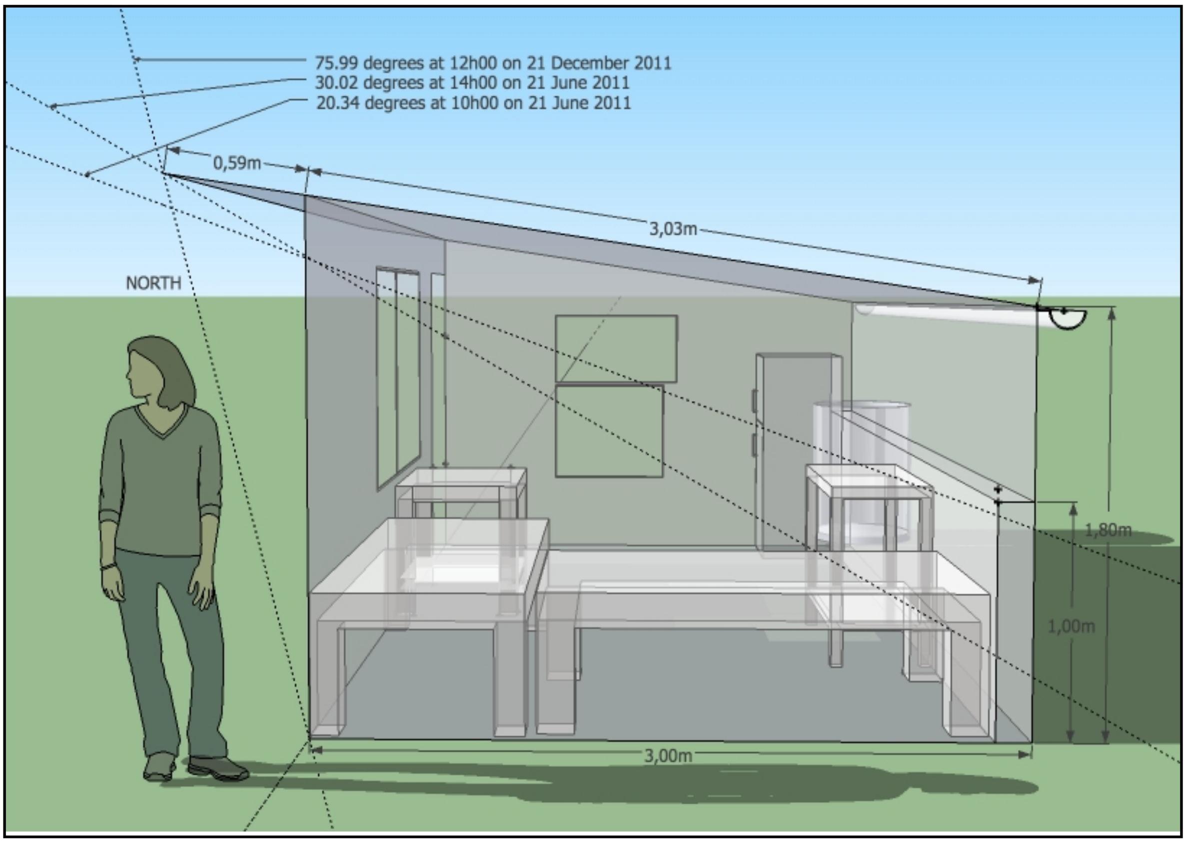


Figure 4.6: iShack – West facing side view
Source: Author (2012) on Google SketchUp

3) Thermal mass – Substances such as bricks and natural rock with high temperature inertia, moderate the indoor temperature fluctuation through their slow absorption and release of heat. These materials should ideally be exposed to sunlight if warmth is required and shaded if a cooling effect is desirous. The iShack was designed to include two thermal mass features:

[34] The natural result of this orientation on the temperatures of various walls is that the northern and western walls are the warmest receiving full front and warm afternoon sunshine respectively. The eastern wall receives the cooler morning sunshine and the south wall is the coldest, never receiving any sun. This is important to be aware of since temperature differences affect indoor air movements, which need to be counteracted or augmented through ventilation measures.

- *Cob Wall* – this inexpensive but highly effective construction technique composed of a simple mixture of sand, water, straw and builder lime (similar to adobe), has been used for millennia (see Figure 4.7). Once cured into a hardened surface, the cob wall acts as thermal mass and insulation. This intervention was placed at the cool southern end of the iShack in order to provide insulation, but more importantly to allow the low lying winter sun to warm up the cob wall through the large north-facing windows (Figure 4.6). The subsequent warmth is radiated into the inner space well into the night. Conversely during summer, when cool indoor temperatures are favorable, the overhang prevents sunlight from striking the cob wall, allowing it to radiate cool air into the interior. The Sustainable by Design database was again used to determine the sun's angles during the warmest part (10h00 to 14h00) of the coldest day of the year (21 June 2011). By positioning the windows to allow the lowest sun angle of the year (20,34°) to pass through the apex of the windows and strike the entire cob wall ensured maximum sunlight during this period. A cob wall height of 0,94m was necessary to achieve this – which was rounded up to 1,0m to match standardised material lengths.

- *Brick Floor* – a paved brick floor acts similarly to the Cob wall given its relative thermal inertia and absorbs the low-lying sunlight during cool winter months. In order to improve the sustainability performance of the iShack and reduce the cost, these were collected from the local landfill site and arranged on top of a thin layer of clay earth which had been collected in Enkanini nearby (Figure 4.7). The bricks had a further advantage of adding a step onto the elevated iShack floor furthermore improving the waterproofing qualities of the structure. A mixture of cement and sand was used to grout the bricks to create a smooth, hygienic indoor surface.

Figure 4.7: Installing Thermal Mass – Cob Wall under construction (left) and Recycled Brick Floor on moist clay (right)
Source: Photographs by Author (2012)

d) Windows

The size and spacing of the windows was an essential ingredient in the enhancement of the thermal comfort of the iShack. Four windows were utilised, three of which had been found in the rubble of a building site (with dimensions 0,7x0,8m; 0,7x1,0m; 1,2mx1,0m) and an additional window was purchased from the informal contractor in Enkanini (dimension 0,9mx0,5m). It was decided to avoid placing windows on the western side, given the excessive heat that would be introduced into the dwelling by the hot afternoon summer sun; as well as the southern wall, which has the opposite effect, being the perennially shady and hence coolest wall. Instead, two smaller windows were placed on the east-facing side in order to capitalise on the warm morning sun, which would provide immediate comfort during cold winter mornings. In summer, the morning sun would not be of unbearable intensity, and a curtain has the ability to curtail unwanted heat from the eastern side. The largest windows and the doorway were placed on the northern, front facing wall, and spaced in such a way that the recycled brick floor and cob wall would receive full sunlight during the warmest period at the height of winter (as discussed above) (Figure's 4.8 & 4.9). In order to optimise on ventilation, the window openings were designed to create a natural draft. The eastern window opens at the bottom in order to draw in the cool heavy air on the shady eastern side during summer, whilst the northern window opens at the top, expelling the rising warm air. In so doing, cool air replaces warm air in an effortless cycle.

e) Roof

Standard material sizes, targeted square meterage and the layout of existing furniture pieces determined the side dimensions of the iShack, which in turn dictated the 8,7° roof pitch. This was deemed steep enough to encourage water runoff into the 5m gutter at the southern end of the roof, which was attached in such a way that water would run off towards one side to allow for rainwater harvesting. Bespoke 3,6m zinc sheets were ordered from Builders Trade Depot, located adjacent to Enkanini (the longest off-the-shelf zinc sheet was 3m), allowing the roof to be covered without a joint. At the same cost per running meter, this was deemed acceptable and is available to all customers. Standard sealed roofing nails secured the zinc roof sheets onto the batons through the elevated undulation of the zinc sheets, improving the water proofing quality further.

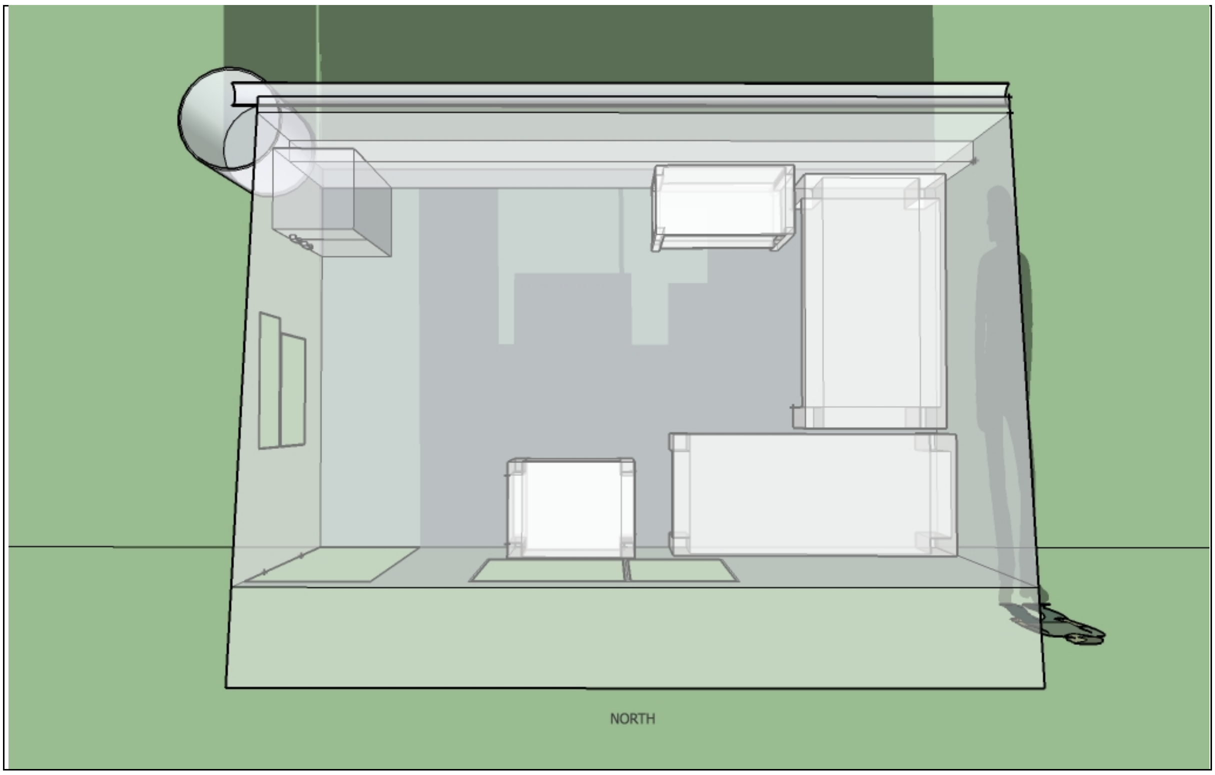


Figure 4.8: iShack Top View
Source: Author (2012) on Google SketchUp

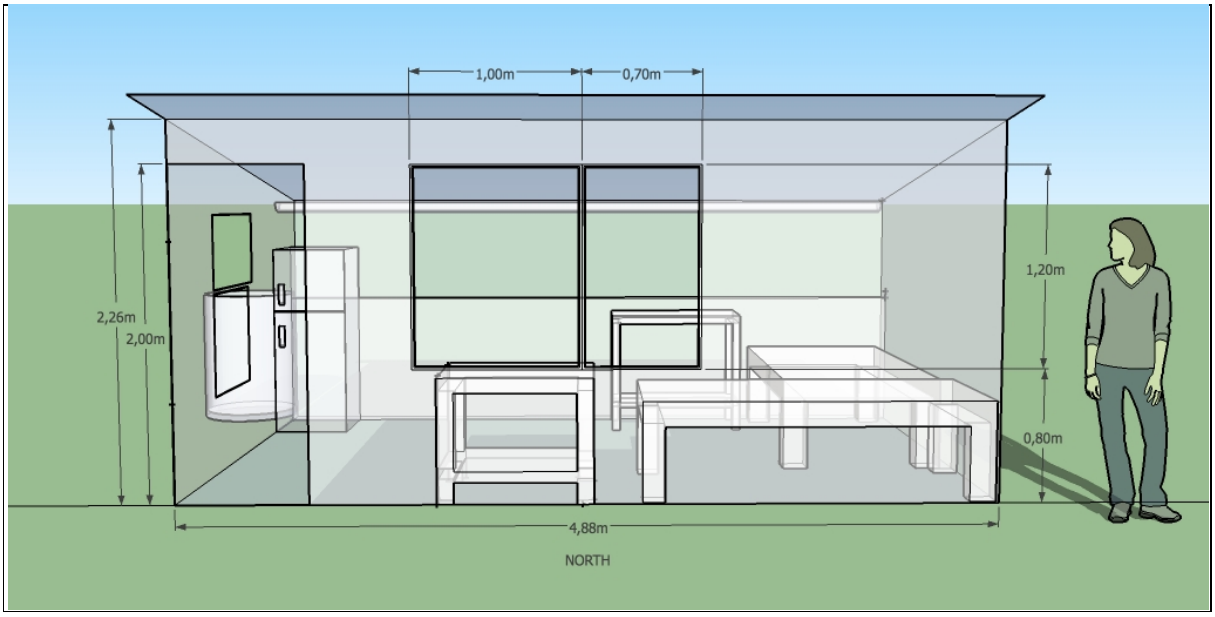


Figure 4.9: iShack North facing front view
Source: Author (2012) on Google SketchUp

4.5.3 Sustainable Energy Technology

In addition to the design interventions, the iShack was fitted with a DC Multigrid system which included two indoor lights, a cellphone charger and outdoor motion activated security light. It was agreed that Plaatjie's contribution towards this system would form part of the 80% contribution she would make from the sale of her materials, as well as a R5 weekly contribution payable to Madiba Galada. The effect of this intervention on thermal performance would likely have been to reduce indoor temperatures relative to the other shacks, since the DC lights replace paraffin and candles – both of which give off significant warmth.

4.5.4 Construction Process

A summary of the construction process is presented in Table 4.1 and may be read in conjunction with the pictorial chronology of construction activities in Appendix C. A motley assemblage of people assisted in constructing the iShack over a period of 16 days – including Kohliso and Mthelo, Galada and the researcher, as well as three neighbours who helped in return for a meal which was prepared every lunchtime. Demonstrating strong leadership qualities, Galada assumed the natural role of site foreman and with the iShack design print outs at hand, oversaw the construction activities. Being a Xhosa speaker, this proved to be extremely helpful since it allowed him to delegate specific tasks according to the skills of each individual and elicit practical advice on certain aspect from the significant construction work experience that was at hand. The construction process took considerably longer than expected due the 'learning-by-doing' ethos, attention to detail and frequent rainfall interruptions.

Table 4.1: iShack construction schedule

Date	Activity	Details
13 - 16 Sept 2011	iShack Site Demarcation & Preparation	Excavation, building soil up, levelling, earth stamping, installation of tyre retaining wall.
20 Sept 2011	Timber Structural Frame	22.5° (NNE) Orientation, measurement, assemblage of all wooden components.
21 Sept 2011	Zinc walls, roof, gutter & windows	Positioning windows into frames & securing all zinc sheets to wooden frame.
22 Sept 2011	Cob wall frame, Floor levelling	Installing cob wall frame & chicken wire and levelling the inside floor.
23 Sept 2011	Cob wall fill, plastering of even mud floor	Preparing cob mixture, filling the form. Levelling of floor with mud-clay mixture.
26 Sept 2011	Preparation of insulation material	Measuring, cutting, sticking tetrapack & cardboard and fire retardant painting.
27 Sept 2011	Brick floor, grouting & door	Placing recycled bricks on hardened floor, even grouting & door placement.
28 Sept 2011	Ceiling & wall insulation	Securing insulation material to wooden frames.
3 Oct 2011	Cob wall plastering, painting	Removing Form, plastering cob wall with clay mixture. Paint touch ups.
6 Oct 2011	Snags	Thorough building check for areas needing attention.

Source: Author (2012)

4.5.5 Costs and Quantities

A schedule of materials cost, quantities and their area of application in the iShack construction is presented in Table 4.2. These figures include an adjustment to correct for project idiosyncrasies, in order to reflect a replicable cost. The cost of a door (R200) and four normal windows (R440) purchased from an informal supplier are thus added, whilst the cost of the windowpanes (R200), installed into the recycled frames, is removed. The normalised iShack cost was thus R5605.98 which adequately fell within the R5750 criterion set above, however it should be noted that this figure excludes the variable costs of transportation and labour which are directly related to the nature of the project – whether it be a self-build, NGO driven or government initiative.

Table 4.2: Schedule of iShack component quantities, application area and incurred costs

Quantity	Description	Application Area	Price
Structural Timber			
3	SABS Pine Pole 50-79mm, CCA treated, 2.1m	Back Structural	R62,58
3	SABS Pine Pole 50-79mm, CCA treated, 2.7m	Middle Structural	R85,86
4	SABS Pine Pole 50-79mm, CCA treated, 3.0m	Front Structural	R130,00
3	SABS Pine 38x114mm, CCA treated, 3.6m	Roofing: Battens	R176,04
3	SABS Pine 50x76mm, CCA treated, 4.8m	Roofing: Rafters	R234,72
1	SAP Pine 38x114mm, CCA treated, 5.1m	Roofing: Fisherboard	R83,44
4	SABS Pine 38x38mm, CCA treated, 3.0m	Circumference Support	R71,76
4	SABS Pine 38x38mm, CCA treated, 4.8m	Circumference Support	R71,76
		Total Structural Timber	*R916,16*
Zinc			
8	Zinc Sheets 0,3mm thick, 3.6m cover (Bespoke)	Roof	R788,42

12	Zinc Sheets 0,3mm thick, 2.1m cover	Walls	R731,20
12	Zinc Sheets 0,3mm thick, 2.4m cover	Walls	R835,57
		Total Zinc	*R2 355,19*
Cob Wall			
1	Straw Bale	Binding Agent	R25,00
5 m	Hexnet Galvanised Fencing 25mm x 1,2m	Stability	R157,38
2	Builders Lime 25kg	Material Stability	R79,32
3	SABS Pine Pole 50-79mm, CCA treated, 1.2m	Frame	R26,19
4	Dropper 35-49mm, CCA treated, 1.8m	Frame	R24,96
2	Dropper 35-49mm, CCA treated, 2.4m	Frame	R11,60
		Total Cob Wall	*R324,45*
Insulation			
25 L	Fire Retardant Paint	Insulation: Ceiling & Wall	R400,00
1	Clothing Dye	Insulation colour stain	R51,20
8	Lattes, 10-32mm, CCA treated, 3.0m	Ceiling insulation support	R96,76
37m^2	Cardboard	Insulation	R0,00
37m^2	Tetrapak	Insulation	R0,00
		Total Insulation	*R547,96*
Windows			
3	Glass Window Panes	Windows	R200,00
5	Meranti Thin 1.8m Window Beading	Window Beading	R61,85
1	Mackie Barrel & Bolt 50mm	Window Lock	R20,19
1	Windows 0,5x0,9m (from local contractor)	Window	R110,00
3	SABS Pine 38x76mm, CCA treated, 2.7m	Window Frame	R80,35
		Total Windows	*R472,39*
Other Materials			
1	Mackie Pro 2 Level Lockset	Door Lock	R60,38
1	Mackie Hinge, Butt & Screws 100mm	Door Hinges	R31,13
14,8m^2	Recyled Bricks	Floor	R0,00
1	Cement 50kg	Brick Floor Grouting	R76,98
6m	Rainflow Gutter D-Shape, Stop End & Bracket)	Gutter	R208,59
5kg	Nails: Various	Everywhere	R172,75
		Total Other Materials	*R549,83*
		Total Project Specific iShack Cost	**R5 165,98**
Normalised Cost Adjustment			
1	Door 0,8x2m (from local contractor)		R200,00
4	Windows 0,5x0,9m (from local contractor)		R440,00
3	Glass Window Panes		-R200,00
		Total Normalised iShack Cost	**R5 605,98**

Source: Author (2012)

4.6 Retrofit Shack and Control Shack

Matching the floor space of all three shacks required extensions to Kohliso (11,32m^2) and Mthelo's (10,84m^2) shacks, at a cost of R877.78 and R790.74 respectively, to match that of Plaatjie's (14,26m^2). Both householders effected the dwelling enlargements themselves after the donation of zinc, timber and nails and agreed to contribute sweat equity through lending their assistance to the iShack construction. The extension was the only measure taken in order to prepare the Control shack for the pilot, save for the installation of measurement equipment (Figure 4.10).

Figure 4.10: The Control shack interior (left) and Retrofit shack interior post installation (right)
Source: Author (2012)

4.6.1 Retrofit Interventions

The design of the retrofit interventions were a direct follow-on from the iShack design phase and were intended to improve the thermal performance of the Retrofit shack through the installation of an additional east-facing window to capitalise on the early morning sun and to improve the indoor ventilation through the formation of a natural draft in conjunction with the existing north-facing window. Cardboard-tetrapak insulation with fire retardant paint was installed on the ceiling and walls, identical to the iShack. Mthelo and a helper installed said items during one day on 6 November 2011, half way through the measurement period (Figure 4.10). The Retrofit interventions are presented in Table 4.3 under the column titled 'Description' and exclude an additional layer of leftover blue paint that Mthelo applied over the two coats of fire retardant paint.

The retrofit intervention described in Chapter 2 included a sustainable energy component, and indeed, this is a distinct possibility for energy poverty alleviation. During the pilot however the researcher chose to limit the analysis to a retrofit insulation and window intervention to isolate their effects, since the introduction of an alternative energy carrier (through sustainable energy technology) and appliance typically involves a change in thermal indoor emissions and would have obscured the accuracy of measuring the precise impact of structural retrofitting.

4.6.2 Retrofit Costs and Quantities

The retrofit window was purchased from the local Enkanini supplier, fire retardant paint from EnviroTouch, Clothing Dye from a local pharmacy, lattes and nails from Builders Trade Depot and came to a total cost of R479,55 (Table 4.3).

Table 4.3: Cost of Retrofit Shack Intervention

Quantity	Description	Application Area	Price
1	Windows 0,5x0,9m (from local contractor)	Ventilation	R110,00
12,5L	Fire retardant paint	Insulation	R200,00
1	Clothing Dye	Walls & Ceiling	R51,20
8	Lattes, 10-32mm, CCA treated, 3.0m	Ceiling insulation support	R96,76
37m^2	Cardboard	Insulation	R0,00
37m^2	Tetrapak	Insulation	R0,00
Various	Nails	Various	R21,59
		Total Retrofit Interventions	**R479,55**

Source: Author (2012)

4.7 Conclusion

In this chapter, two additional energy-shelter incremental stages were defined, designed and developed, namely the Retrofit and iShack. Social, legal and administrative, and a transdisciplinary design process converged to deliver the final iShack and Retrofit designs which were constructed on a municipality sanctioned site with the cooperation of willing pilot participants. In order to test the thermal performance and thermal comfort performance of the developmental responses under analysis, data measurements were collected over a 7-week period, which will be analysed and interpreted in the following Chapter.

Chapter Five: Measurement Results

5.1 Introduction

The high-level objective of the analysis in the results section is to identify the thermal performance and thermal comfort performance of the two additional energy-shelter increments proposed in this study. More specifically, the investigations in this chapter aims to isolate the effect of Ecological Design and Sustainability Features (iShack) and retrofit interventions (Retrofit shack) over that of a standard shack (Control shack). Indoor and Outdoor Temperature readings were recorded at 15-minute intervals for all shacks over the period of 10 October to 30 November 2011, giving 52 days of continuous data readings. The Retrofit shack was a standard shack that had the retrofit interventions installed on 4 November 2011, i.e. half way through the measurement period, giving 26 days of data readings before and after retrofitting.

Thermal performance refers to a comparative analysis of the correlation between Indoor and Outdoor Temperature (Section 5.2), their absolute levels (Section 5.3), the magnitude of differences between them (Section 5.4) and rates of change (Section 5.5) during the coolest (01h00 to 06h00) and warmest (11h00 to 15h00) parts of the day for all three shacks. These metrics are repeated at three different Outdoor Temperature categories to gain a closer understanding of Indoor Temperature movements on mild, warm and hot days (Sections 5.3.2 and 5.4.2).

Thermal comfort performance (Section 5.6) relates to an objectified assessment of the Thermal Performance measures through the introduction of Holm and Engelbrecht's (2005) adaptive thermal comfort methodology for free flowing (naturally ventilated) buildings. The sterile Thermal Performance metrics are thus contextualised and humanised through this additional analysis, given that the methodology was developed through user responses to varying climatic conditions and is particularly applicable to the South African environment.

Results Section Reading Guide

For ease of reading, the Retrofit shack will be referred to as 'Retrofit (before)' and 'Retrofit (after)' in the text, which denotes the periods and data observations before and after installation of retrofit interventions respectively. For completeness sake, tables include all measurement results of the period under analysis, however only salient figures, as they relate to the discourse, will be highlighted.

5.2 Indoor and Outdoor Temperature Correlations

Analysing the Correlation between Indoor and Outdoor Temperatures is an appropriate means by which to commence a Thermal Performance analysis, given that Outdoor Temperature is the primary driver of Indoor Temperature. Figures 5.1.1 – 5.1.3 are Indoor and Outdoor Temperature data points plotted against time for the Control shack, iShack and Retrofit shacks respectively and expose the daily fluctuations of these two metrics. The band of Indoor Temperature fluctuations for the iShack is narrower in comparison to the Control shack indicating a reduced variance in Indoor Temperature over time. This narrower amplitude in Indoor Temperature fluctuations is confirmed by the Control shack standard deviation of 6,25°C (with mean of 19,81°C), compared to a lower iShack standard deviation of 4,22°C (with mean of 21,42°C) (Table 5.1).

Table 5.1: Summary statistics for Control, iShack and Retrofit shack

	Arithmetic Mean	Standard Deviation	Correlation Coefficient
Control	19.81°C	6.25°C	0.978
iShack	21.42°C	4.22°C	0.892
Retrofit (Before)	19.78°C	5.19°C	0.957
Retrofit (After)	21.63°C	4.77°C	0.922

Source: Author (2012)

An observation can be made that the Indoor Temperature (thin blue line) movements follow the Outdoor Temperatures (thin red line) almost perfectly for the Control shack (Figure 5.1.1), whilst an Indoor Temperature divergence is observable in the iShack (Figure 5.1.2). These trends are confirmed by the Correlation coefficients[35] of 0,978 and 0,892 for the Control and iShack respectively (Table 5.1), which both demonstrate strong positive relationships between Indoor and Outdoor Temperatures, albeit a significantly weaker one for the iShack. Furthermore, observable is the fact that Control shack Indoor Temperatures exceed the Outdoor Temperatures at warmer parts of the day, yet match Outdoor Temperatures at cooler parts of the day; whilst the iShack Indoor Temperatures decouple from Outdoor Temperatures at cooler temperatures and match Outdoor Temperatures at warmer periods of the day. These trends will be investigated further in the ensuing analyses.

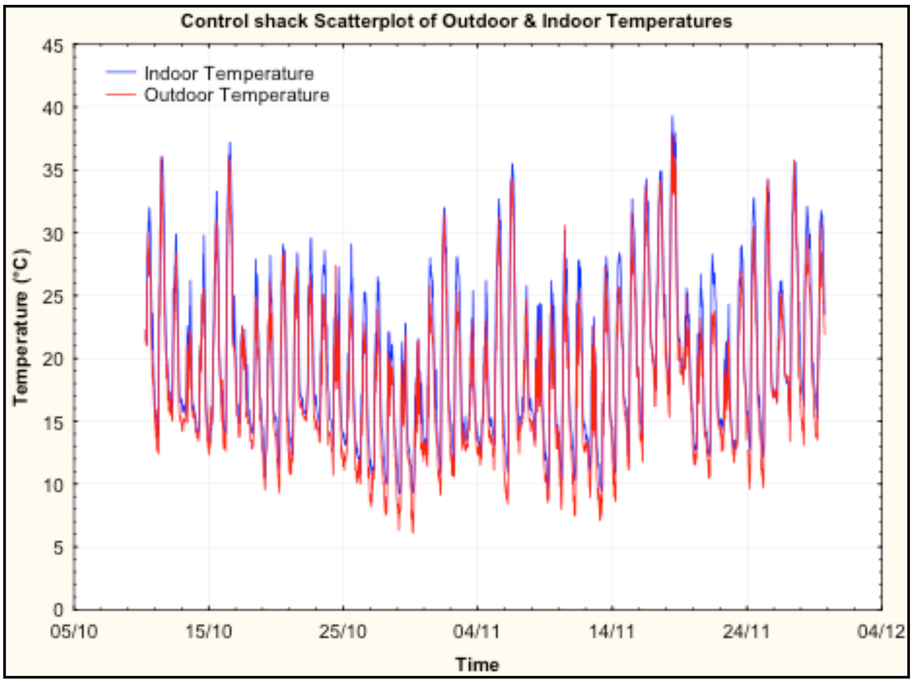


Figure 5.1.1:Control shack Indoor and Outdoor Temperature over time

Source: Author (2012)

[35] The Sample Coefficient of Correlation (r) is a measure of the degree to which an independent and dependent variable are related, and ranges between -1 and +1, with -1 implying a perfect negative linear relationship, and +1 a perfect linear positive relationship (Keller & Warrack, 2000).

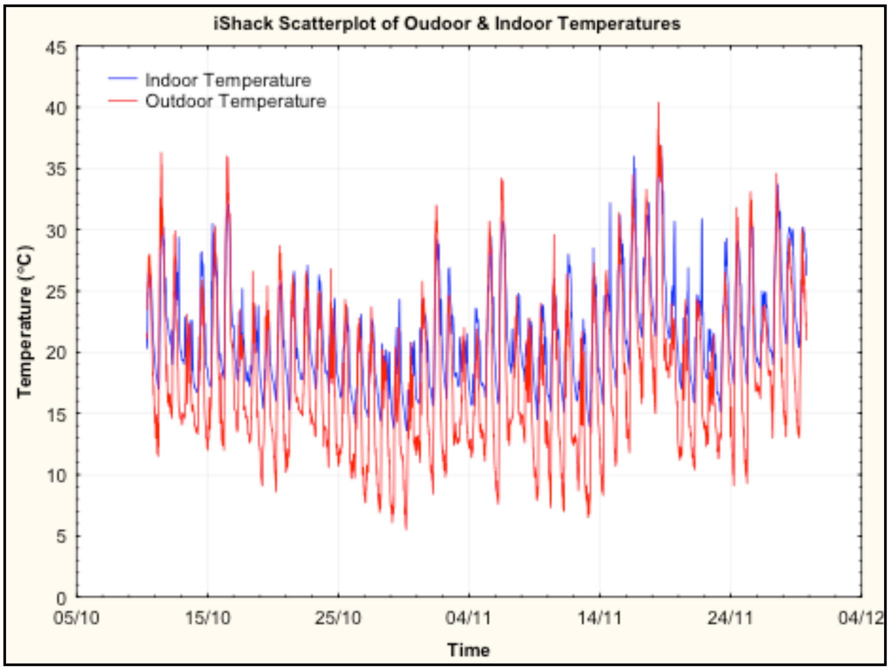


Figure 5.1.2: iShack Indoor and Outdoor Temperatures over time
Source: Author (2012)

A preliminary analysis of the relationship between Indoor and Outdoor Temperatures for the Retrofit (before) and Retrofit (after) shacks (Figure 5.1.3) reveal an Indoor Temperature decoupling effect at cooler and warmer temperatures for the Retrofit (after) shack, evidenced graphically by a reduction in the degree to which Indoor Temperatures exceed Outdoor Temperatures at warmer parts of the day, and an increase in Indoor Temperatures at cooler Outdoor Temperatures. This tapered effect is due to a reduction in Indoor Temperature fluctuations evidenced by a minor reduction in standard deviation from 5,19°C to 4,77°C from a mean of 19,78°C and 21,63°C respectively. This trend is further substantiated by a minor reduction in correlation coefficient from 0,957 to 0,922, suggesting a slight reduction in the strength of the relationship between Indoor and Outdoor Temperatures for the Retrofit (before) and Retrofit (after) shacks respectively.

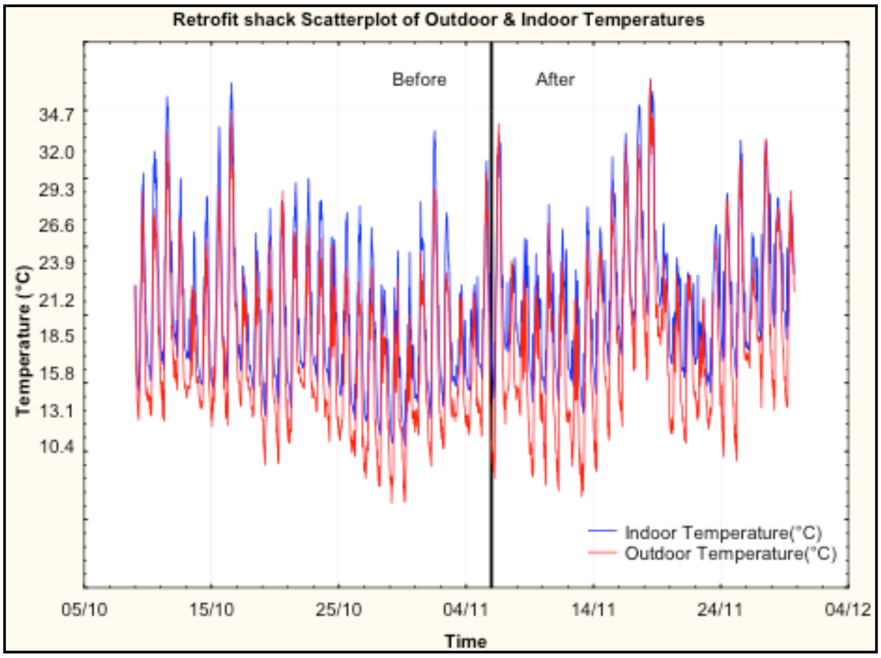


Figure 5.1.3: Retrofit Shack Before and After Indoor and Outdoor Temperatures over time
Source: Author (2012)

The Temperature Correlation analysis has shed light on the strength of the relationship between Indoor and Outdoor Temperatures. To gain an understanding of the thermal performance in absolute and relative terms, further investigations are required.

5.3 Indoor Temperature Movements

A comparative analysis of hourly mean Indoor temperatures is useful in deriving the relative thermal performance at different times of the day, whilst simultaneously giving a graphical overview of the hourly Indoor temperature bands of the sample shacks. An initial analysis will be conducted by hour (Section 5.3.1) and then further disaggregated into three Outdoor Temperature categories (Section 5.3.2) to derive a more fine-tuned picture of the relative Indoor Temperature behaviours at various levels.

Indoor temperature observations were rounded up or down to the nearest hour, the results were averaged across the sample and plotted at hourly increments. The objective of this investigation is a) to ascertain the range of average Indoor Temperature fluctuations for a given shack and b) to discern the magnitude of the difference in Indoor Temperature during the Coolest (01h00 to 06h00) and Warmest (11h00 to 15h00) parts of a given day. The ensuing analysis is divided into the time periods *Before Retrofit* and *After Retrofit*. This was necessary, since, in the interest of accuracy, any comparison between the Retrofit shack and the Control or iShack needed to correspond to the same time period.

Outside Temperatures were constant for all three shacks given that the recordings were taken in the same immediate environment. The logical step would have been to find the mean of all three Outside Temperature readings and to use this as a standard against which Indoor Temperatures of individual shacks could have been compared. This however was not possible due to the asynchronised nature of time readings between the three shacks[36]. This effect was corrected for by using hourly time increments (Hour 1, Hour 2… Hour 24) and averaging Indoor and Outdoor Temperatures within these increments into a single number. Thus, Indoor Temperature and Outdoor Temperature were directly comparable and the resultant Temperature Difference & Time coordinates were plotted at hourly increments to shed light on the relevant shack performances over a 24-hour cycle. Using this hourly approach is coarser than using 15-minute time intervals; however, it still meets the overall objective of measuring intra-shack Temperature Difference levels at different time periods.

Guide to reading Tables

From this point forward, all tables read as follows: 'Cool' refers to the time period of 01h00 to 06h00; 'Warm' refers to the time period of 11h00 to 15h00; 'Range' is the average Indoor Temperature fluctuation between the average of daily 'Cool' and 'Warm' periods; 'Daytime Var' is the average difference in Indoor Temperature between the 'Cool' or the 'Warm' periods of the day. In order to shed light onto the comparative differences in Ranges between shacks, these figures are calculated too.

in °C	Cool	Warm	*Range*
Control	A	C	*C-A*
iShack	B	D	*D-B*
Daytime Var	*B-A*	*D-C*	*(D-B)-(C-A)*
Retro(Before)	X	Y	*Y-X*
Retro(After)	Z	Q	*Q-Z*
Daytime Var	*Z-X*	*Q-Y*	*(Q-Z)-(Y-X)*

5.3.1 Analysis by Hour

Before Retrofit

In Figure 5.2.1, a bell shaped curve of Indoor Temperature changes is discernable for all 3 shacks with lower temperatures in the morning and evening and a rise during the daytime. Observable from Table 5.2.1 is that the Indoor Temperature range for the iShack (6,62°C) was 5,39°C narrower than the Control shack (12,01°C), a fact that is graphically confirmed in Figure 5.2.1. Furthermore, the iShack was 3,44°C warmer during the Coolest part of the day and 1,95°C cooler during the Warmest part of the day in comparison to the Control shack, suggesting superior iShack's thermal performance at cooler periods of the day, something that was identified in Section 5.3 above, and which will be examined further below.

Table 5.2.1: Summary statistics of Indoor Temperature changes by hour – before Retrofit

in °C	**Cool**	**Warm**	***Range***
Control	13,58	25,59	*12,01*
iShack	17,02	23,64	*6,62*
Daytime Var	*3,44*	*-1,95*	*-5,39*
Retro(Before)	14,95	25,56	*10,61*

[36] In other words, the Control shack might have recorded a data point at 15h15 and 15h30, and the iShack at 15h16 and 15h31, something that is unavoidable when using three different data loggers, even after calibration. Using an average Outdoor Temperature dataset composed of all three Outdoor Temperature datasets would have introduced the problem of attempting to match average asynchronised Outdoor Temperatures with individual shack asynchronised Indoor Temperatures.

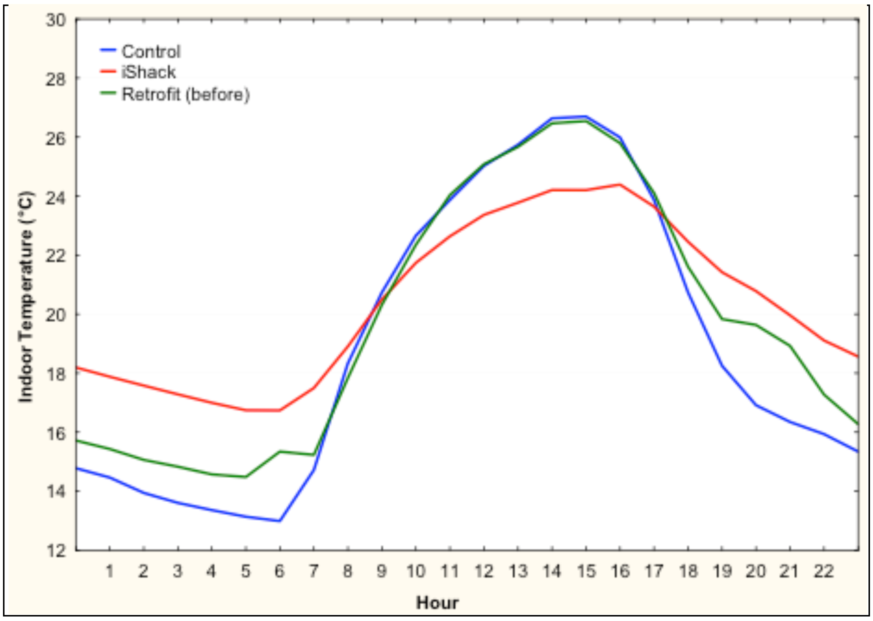


Figure 5.2.1: Mean Indoor Temperature categorised by hour – before Retrofit
Source: Author (2012)

After Retrofit

Continuing the analysis during the period after retrofitting, in Figure 5.2.2, a closer approximation of the Retrofit (after) Indoor Temperatures to that of the iShack is evident. The Indoor Temperatures occupy a narrower range and present a divergent trend from the period before retrofitting, where the Retrofit (before) shack matched the Indoor Temperature movements of the Control shack (in Figure 5.2.1).

The effect of retrofitting on thermal performance is now discernable. A narrowing of the Indoor Temperature band between the Retrofit (before) (10,61°C) and Retrofit (after) (8,52°C) shacks to the order of 2,09°C is noticeable. On average, the retrofit installations made the Retrofit shack 2,73°C and 0,64°C warmer during the coolest and warmest part of the day. It would thus appear as though retrofit interventions did not render a cooling effect during warmer Outdoor Temperatures. In order to gain greater insight into the drivers behind this apparent effect, as well as a more nuanced appreciation of the thermal performance of all shacks, it may be useful to break the Outdoor Temperature's into categories to assess the Indoor Temperature performances in relation to them.

Table 5.2.2: Summary statistics of Indoor Temperature changes by hour – after Retrofit

in °C	Cool	Warm	*Diff (D)*
Control	14,45	27,92	*13,47*
iShack	18,50	26,26	*7,76*
Diff (S)	*4,05*	*-1,66*	*-5,71*
Retro(Before)	14,95	25,56	*10,61*
Retro(After)	17,68	26,20	*8,52*
Diff (S)	*2,73*	*0,64*	*-2,09*

Source: Author (2012)

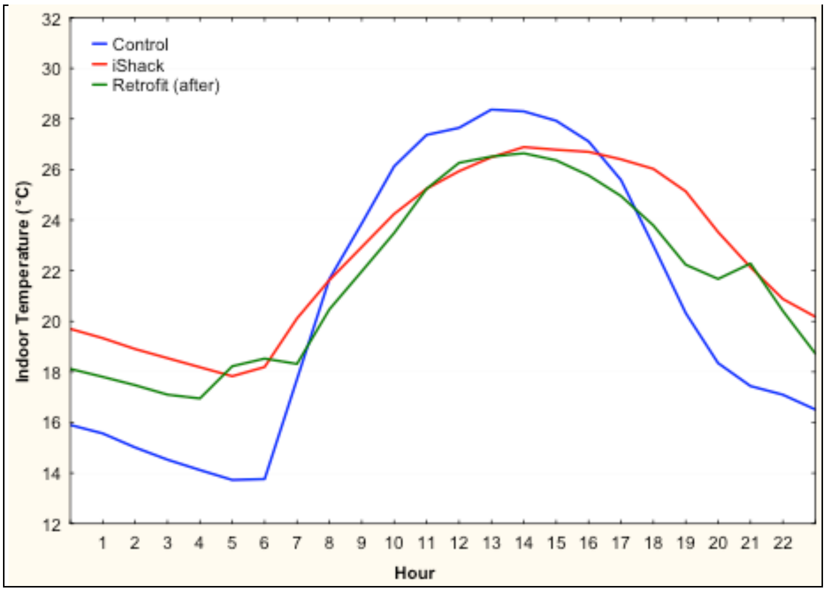


Figure 5.2.2: Mean Indoor Temperature categorised by hour – after Retrofit
Source: Author (2012)

5.3.2 Analysis by Outdoor Temperature categories

To enable this deeper analysis, three daily maximum Outdoor Temperature categories were constructed, namely <25°C; 25-30°C;≥30°C, which are called Mild, Warm and Hot days respectively[37]. According to this categorisation, corresponding Indoor Temperatures were grouped into hourly increments, averaged and plotted in accordance to their Outdoor Temperature category. This disaggregation enables the comparison of Indoor Temperature ranges and levels at three different Outdoor Temperature categories for all three shacks. To illustrate the meaning of this assessment, the Daily Difference of 15,92°C for the Control shack at Outdoor Temperature category ≥30°C from Table 5.3.1 may be regarded. This result implies that on Hot days (≥30°C), the Indoor Temperature range between the average Coolest (01h00 to 06h00) and Warmest (11h00 to 15h00) period of the day was 15,92°C.

Before Retrofit

A preliminary analysis of the trendlines in Figure 5.3.1 reveal that the Control and Retrofit shack Indoor Temperatures (green and yellow lines) operate within a larger overall Indoor Temperature range compared to the iShack (red lines). This is confirmed by the results in Table 5.3.1, where the mean Indoor Temperature analysis at the coolest and warmest parts of the day was repeated. The iShack's reduced Indoor Temperature bands at all Outdoor Temperature categories compared to the Control shack are reflected, in the order of 4,89°C at milder Outdoor Temperatures (category <25°C); 5,49°C at warm Outdoor Temperatures (category 25-30°C); and 7,22°C at hot Outdoor Temperatures (category ≥30°C). The average Indoor Temperature fluctuations are thus significantly lower for the iShack and the least at cooler temperatures.

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[37] Given that the lowest maximum Outdoor Temperature for the period under analysis was 20,63°C, the next convenient interval that was chosen was 25°C, with subsequent 5°C increments.

Comparing the Control and iShack at mean daily temperature extremes ('Cool' and 'Warm' on Table 5.3.1), reveals that the iShack performs best at Cooler temperatures on Mild days given the intra-shack Indoor Temperature difference of 3,94°C, followed by cool periods on hot days (difference of 3,36°C) and warm days (difference of 3,45°C). This trend is reversed during warmer Outdoor Temperature categories, where the iShack was 3,77°C cooler, 2,13°C cooler and 0,95°C warmer on hot, warm and mild days respectively.

Table 5.3.1: High and Low Indoor Temperature Ranges for Outdoor Temperature Categories – before Retrofit

in °C	<25°C			25-30°C			≥30°C		
	Cool	**Warm**	***Range***	**Cool**	**Warm**	***Range***	**Cool**	**Warm**	***Range***
Control	12,67	21,95	*9,28*	14,35	26,19	*11,84*	14,04	32,3	*18,26*
iShack	16,61	21	*4,39*	17,71	24,06	*6,35*	17,49	28,53	*11,04*
Daytime Var	*3,94*	*-0,95*	-4,89	*3,36*	*-2,13*	-5,49	*3,45*	*-3,77*	-7,22
Retro(Before)	14,08	22,05	*7,97*	15,53	26,18	*10,65*	15,6	31,99	*16,39*

Source: Author (2012)

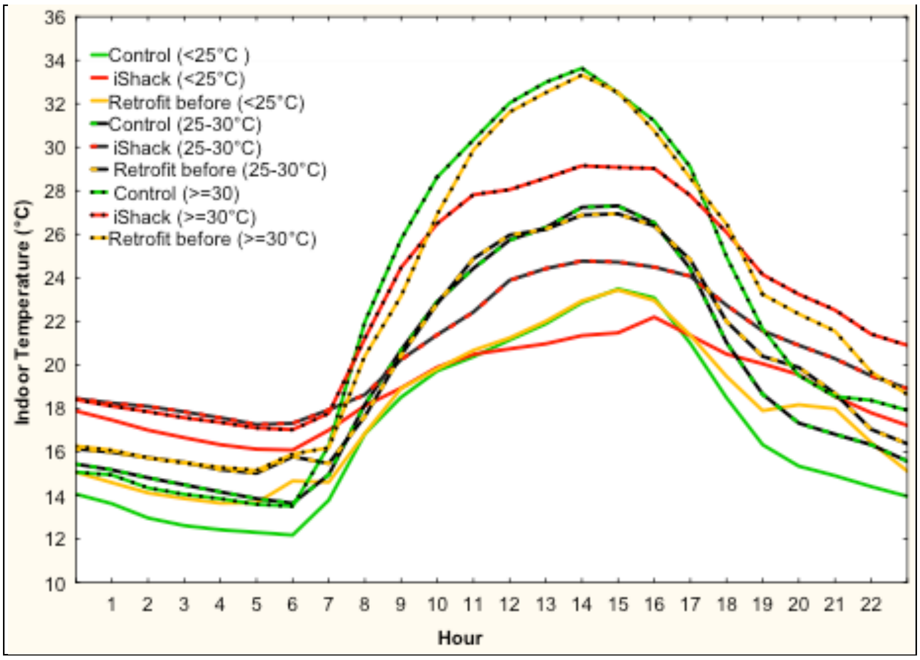

Figure 5.3.1: Mean Indoor Temperatures by hour for Temperature Categories – before Retrofit
Source: Author (2012)

After Retrofit

The above analysis was repeated for the period corresponding to after the retrofit installations. An initial assessment of the trendlines in Figure 5.3.2 suggests a closer relationship between the iShack and Retrofit (after) shacks at all Outdoor Temperature categories compared to the time period before retrofit, where the Indoor Temperature movements of the Retrofit (before) shack followed that of the Control Shack (Figure 5.3.1). These trends are confirmed in Table 5.3.2, where the differences between Cool and Warm periods of the day are closely associated between the iShack and Retrofit (after) shack. The Control Shack and iShack differences are consistent with those of the Retrofit (before) period. Furthermore, the effect of retrofitting is now discernable in Table 5.3.2.

Retrofitting narrowed Indoor Temperature ranges by 3,84°C on mild days and widened it on warm and hot days by 0,92°C and 1,25°C respectively. Save for minor underlying changes in Outdoor Temperatures over the time period (the effect of which will be factored into an analysis in Section 5.5 below), a warming effect in the order of 3,57°C, 0,65°C and 1,21°C during Cool periods on mild, warm and hot days respectively can be identified. In line with a narrower Indoor Temperature band, the Warm periods of all Outdoor Temperature categories were also reduced by a magnitude of 0,27°C, 1,57°C and 2,46°C on mild, warm and hot days respectively. These results are in line with those of the iShack, which showed improved performance at cooler temperatures and on milder days compared to the Control shack.

Table 5.3.2: High and Low Indoor Temperature Ranges for Outdoor Temperature Categories – after Retrofit

in °C	<25°C			25-30°C			≥30°C		
	Cool	Warm	*Range*	Cool	Warm	*Range*	Cool	Warm	*Range*
Control	14,66	22,83	*8,17*	12,65	27,73	*15,08*	15,45	33,17	*17,72*
iShack	18,31	22,16	*3,85*	16,98	26,02	*9,04*	19,70	30,50	*10,8*
Daytime Var	*3,65*	*-0,67*	*-4,32*	*4,33*	*-1,71*	*-6,04*	*4,25*	*-2,67*	*-6,92*
Retro(Before)	14,08	22,05	*7,97*	15,53	24,06	*8,53*	17,49	28,53	*11,04*
Retro(After)	17,65	21,78	*4,13*	16,18	25,63	*9,45*	18,70	30,99	*12,29*
Daytime Var	*3,57*	*-0,27*	*-3,84*	*0,65*	*1,57*	*0,92*	*1,21*	*2,46*	*1,25*

Source: Author (2012)

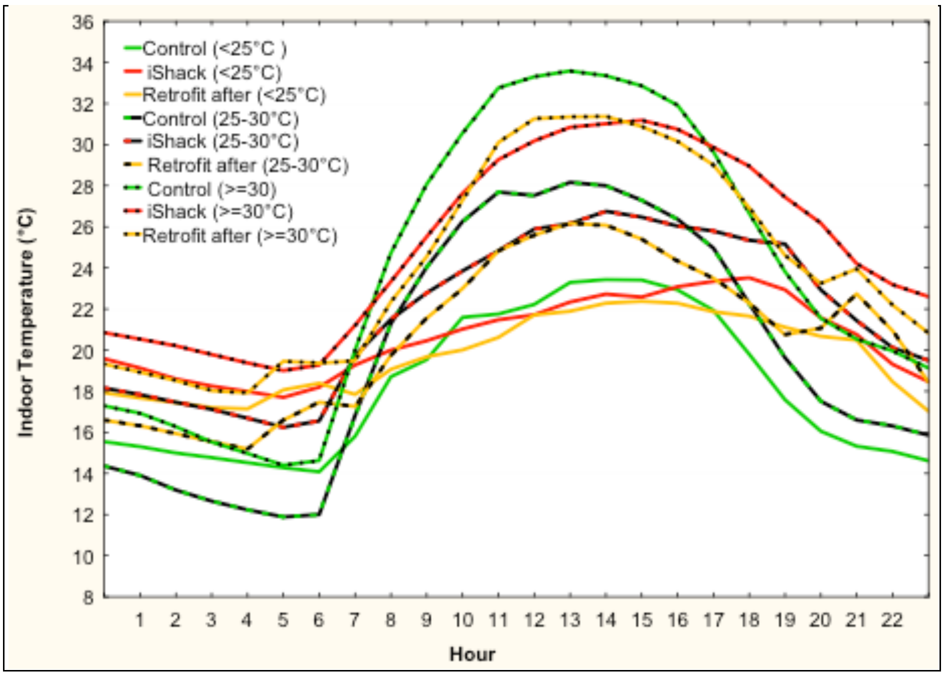

Figure 5.3.2: Mean Indoor Temperatures by hour for Temperature Categories – after Retrofit

Source: Author (2012)

Comparing the Retrofit shack Indoor Temperature before and after retrofitting does not give a conclusive indication of the effect of interventions given their recordings over two different time periods, with variations in underlying Outdoor Temperatures. For this, an alternative means of calculating the effect of retrofit interventions is required, namely by measuring the 'buffer effect', that is, the difference between Indoor and Outdoor Temperatures at different time intervals – an analysis that can be extend to all shacks.

5.4 Temperature Differences – 'The Buffer Effect'

Thermal comfort is a function of both Indoor and Outdoor Temperature, amongst other factors (discussed in greater detail in Section 5.6 below). The difference between the two metrics is indicative of the degree to which a dwelling buffers external temperature stimuli, and may thus be deemed to be an indicator of a dwelling's thermal performance.

In the following analysis, Temperature Difference was derived by subtracting mean hourly Indoor Temperature from mean hourly Outdoor Temperature. Negative Temperature Differences are indicative of higher Indoor Temperatures (Indoor>Outdoor), whilst positive Temperature Differences imply lower Indoor Temperatures (Indoor<Outdoor). From a comfort perspective it would thus be preferable to have a relatively higher negative Temperature Difference during cooler times (early morning & night) and a relatively higher positive Temperature Difference during warm periods.

From a thermal performance perspective, a larger Temperature Difference band between average daily Cool and Warm periods is desirable, since this indicates a larger divergence (i.e. buffering effect) between Indoor and Outdoor Temperatures. Furthermore, positive Temperature Differences between Cool and Warm periods are favourable, since this indicates a bell shaped graph, implying larger negative Temperature Differences in morning and evening and relatively more positive Temperature Differences around midday.

Given the consistent Outdoor Temperature across all shacks and time periods, the magnitude of differences between the Coolest and Warmest daily periods will be the similar as in Section 5.3, and will thus not be repeated here[38].

5.4.1 Analysis by hour

Before Retrofit

An examination of the trend lines in Figure 5.4.1 reveal a smooth bell-shaped curve for the iShack implying gradual and even Indoor Temperature changes in response to Outdoor Temperature changes throughout the day. The jagged line and shear changes of the Control and Retrofit (before) shacks are indicative of relatively higher reactivity of the indoor climate to changes in Outdoor Temperature (an analysis of the lag effect of Indoor Temperature to Outdoor Temperature stimuli is conducted in Section 5.5), something that may to a large degree be attributed to user activity, such as cooking.

[38] This is proved by the following formula: [Control (Outdoor Temp – Indoor Temp)] – [iShack (Outdoor Temp – Indoor Temp)] = Indoor Temp (Control – iShack), which is precisely the analysis that has been conducted already in Section 6.3.2.

Table 5.4.1: Mean Temperature Differences at Daily Temperature Extremes – before Retrofit

in °C	Cool	Warm	*Diff (D)*
Control	-1,24	-2,05	*-0,81*
iShack	-5,17	-0,23	*4,94*
Diff (S)	*3,93*	*-1,82*	*5,75*
Retro(Before)	-2,83	-2,95	*-0,12*

Source: Author (2012)

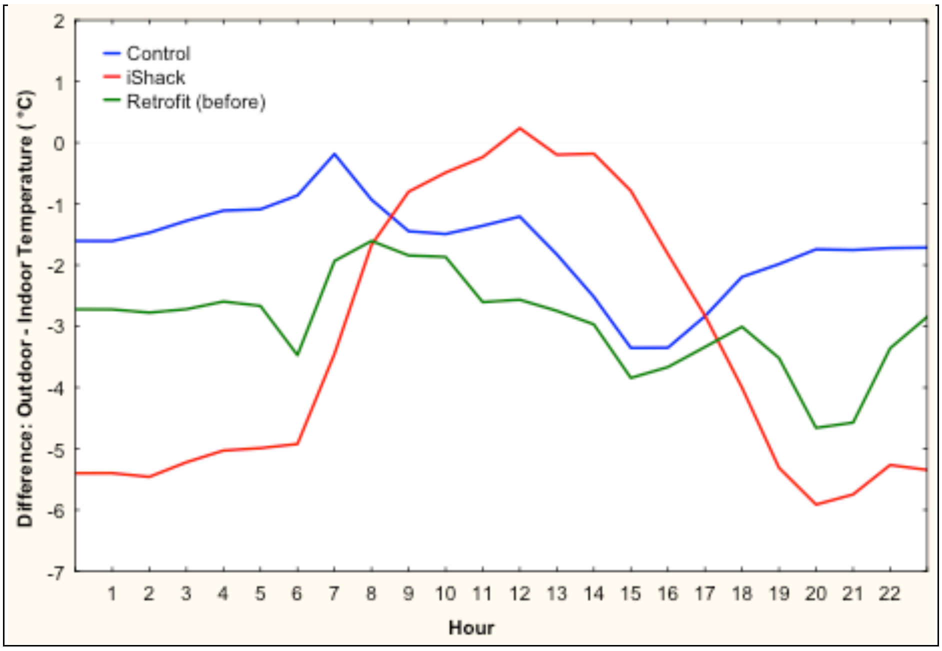

Figure 5.4.1: Mean Difference between Indoor and Outdoor Temperature's at hourly increments – before Retrofit
Source: Author (2012)

An analysis of the Temperature Difference bands in Table 5.4.1 reveals that the iShack's buffer effect of 5,75°C was larger than that of the Control shack of 0,81°C during the Coolest and Warmest daily periods. This implies that relative to Outside Temperature (which fluctuates drastically throughout the day), Indoor Temperature was the most divergent (i.e. did not fluctuate as much) for the iShack.

After Retrofit

Continuing the examination after the retrofit, In Figure 5.4.2, the Retrofit (after) measurements show a marked convergence towards that of the iShack, approximating its smooth bell shaped curve with a few kinks betraying user activity, e.g. the sharp increase in Indoor Temperature around 05h00, which may be attributed to morning water heating/cooking activities in the Retrofit (after) household. This is a departure from the period before retrofitting, where the Retrofit (before) shack assumed a similar shape to the Control shack (Figure 5.4.1).

Table 5.4.2: Mean Temperature Differences at Daily Temperature Extremes – after Retrofit

in °C	Cool	Warm	*Diff (D)*
Control	-1,33	-2,44	*-1,11*
iShack	-5,62	-0,69	*4,93*
Diff (S)	*4,29*	*-1,75*	*6,04*
Retro(Before)	-2,83	-2,95	*-0,12*
Retro(After)	-4,53	-1,76	*2,77*
Diff (S)	*1,70*	*-1,19*	*2,89*

Source: Author (2012)

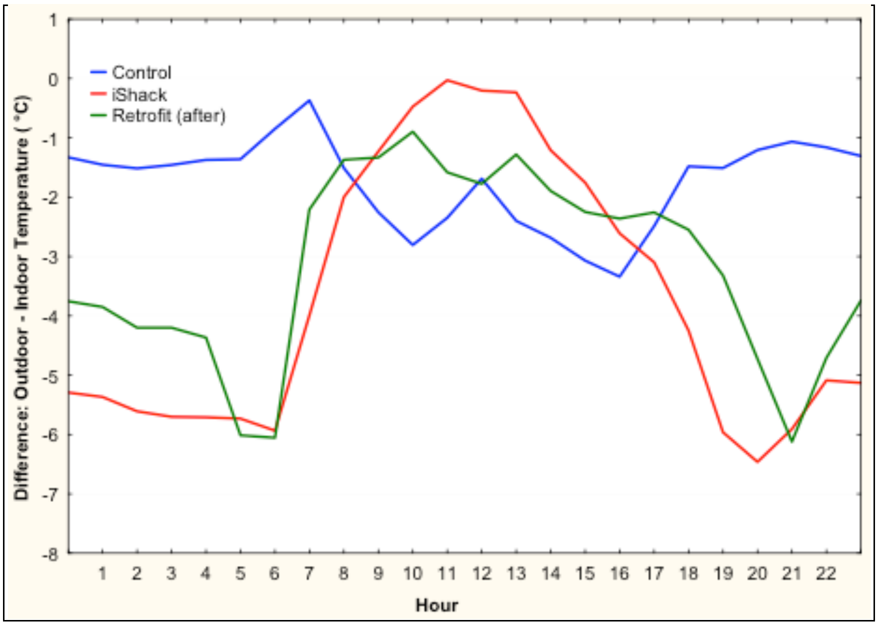

Figure 5.4.2: Mean Difference between Indoor and Outdoor Temperature's at hourly increments – after Retrofit

Source: Author (2012)

Isolating the effect of retrofitting in Table 5.4.2 reveals an overall improvement of 1,7°C during cooler and 1,19°C during warmer periods of the day respectively as well as an increase in the dwelling buffer effect of 2,89°C.

5.4.2 Analysis by Outdoor Temperature categories

The Temperature Difference analysis is continued in this section through a disaggregation of hourly average Indoor Temperatures in accordance to the three Outdoor Temperature categories used above, in order to identify the efficacy of the buffer effect of the iShack and Retrofit interventions. The methodological approach described in Section 5.4 applies.

Before Retrofit

In Figure 5.5.1, Temperature Differences are delineated according to daily maximum Outdoor Temperature categories before the retrofit. The bands within which the various shacks operate are now clearly identifiable. Observable is a desirable larger Temperature Difference range at all categories for the iShack (red lines) followed by narrower bands for the Control and Retrofit (before) shacks. In Table 5.5.1, numbers are added to these trends. A comparison of the Control and iShack variances in Temperature Differences reveals the greatest buffer effect on Hot days (≥30°C) of 7,49°C followed by Warm (25-30°C) days of 5,65°C and Mild days (<25°C) of 5,03°C.

Table 5.5.1: Mean Hourly Temperature Differences by Outdoor Temperature Categories – before Retrofit

in °C	<25°C			25-30°C			≥30°C		
	Cool	Warm	*Diff (D)*	Cool	Warm	*Diff (D)*	Cool	Warm	*Diff (D)*
Control	-1,47	-1,97	*-0,5*	-1,14	-2,15	*-1,01*	-0,92	-1,99	*-1,07*
iShack	-5,73	-1,2	*4,53*	-4,78	-0,14	*4,64*	-4,73	1,69	*6,42*
Diff (S)	*-4,26*	*0,77*	*5,03*	*-3,64*	*2,01*	*5,65*	*-3,81*	*3,68*	*7,49*
Retro(Before)	-3,15	-2,85	*0,3*	-2,55	-2,91	*-0,36*	-2,73	-4,71	*-1,98*

Source: Author (2012)

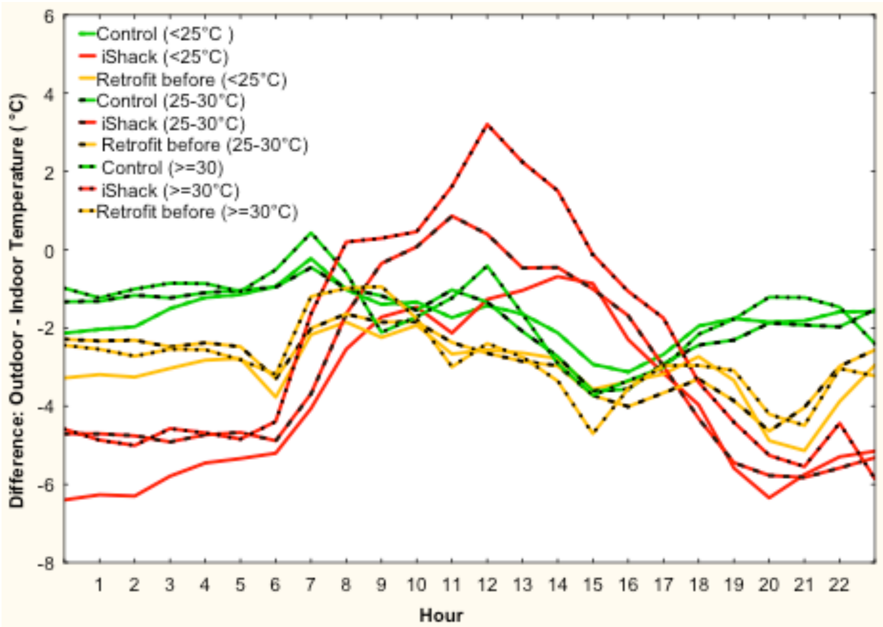

Figure 5.5.1: Mean Hourly Temperature Differences by Outdoor Temperature Categories – before Retrofit
Source: Author (2012)

After Retrofit

The effect of retrofitting is clearly discernable graphically in Figure 5.5.2 where the Temperature Difference trend of the Retrofit (after) shack approximates the bell-shape of the iShack, a departure from the previous trend where the Retrofit (before) shack assumed a similar trend to the Control shack (Figure 5.5.1). The results in Table 5.5.2 indicate that retrofitting an existing shack had the greatest buffer effect on Hot days (≥30°C), increasing the difference between Indoor and Outdoor Temperatures by 5,43°C, followed by Warm days (25-30°C) of 3,83°C and Mild days (<25°C) of 1,97°C.

Table 5.5.2: Mean Hourly Temperature Differences for Outdoor Temperature Categories – after Retrofit

in °C	<25°C			25-30°C			≥30°C		
	Cool	Warm	*Diff (D)*	Cool	Warm	*Diff (D)*	Cool	Warm	*Diff (D)*
Control	-0,89	-2,24	*-1,35*	-1,93	-2,97	*-1,04*	-1,47	-2,28	*-0,81*
iShack	-4,79	-1,83	*2,96*	-6,46	-0,99	*5,47*	-6,03	0,65	*6,68*
Diff (S)	*-3,90*	*0,41*	*4,31*	*-4,53*	*1,98*	*6,51*	*-4,56*	*2,93*	*7,49*
Retro(Before)	-3,15	-2,85	*0,30*	-2,55	-2,91	*-0,36*	-2,73	-4,71	*-1,98*
Retro(After)	-4,17	-1,90	*2,27*	-5,50	-2,03	*3,47*	-4,91	-1,46	*3,45*
Diff (S)	*-1,02*	*0,95*	*1,97*	*-2,95*	*0,88*	*3,83*	*-2,18*	*3,25*	*5,43*

Source: Author (2012)

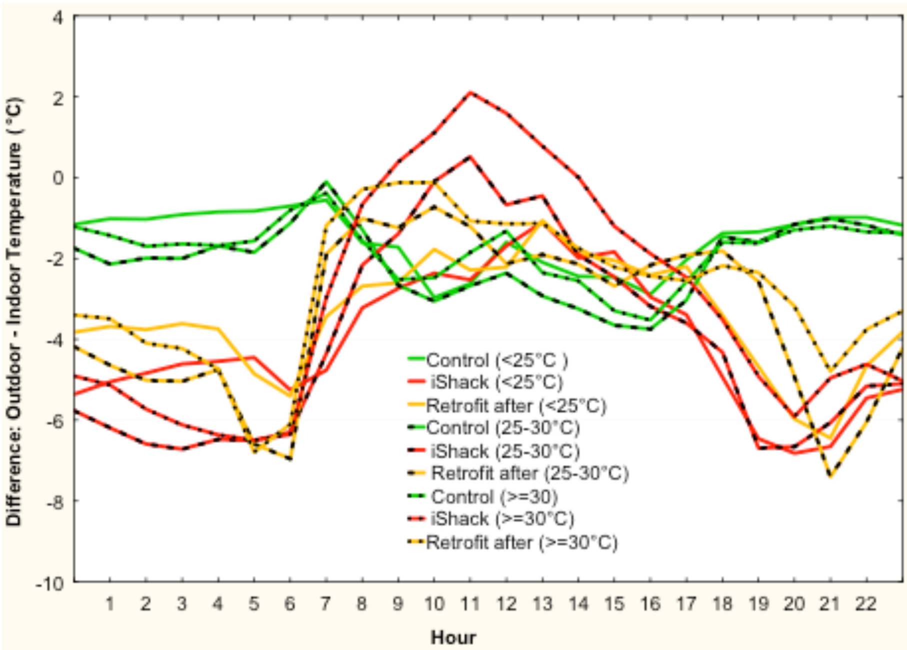

Figure 5.5.2: Mean Hourly Temperature Differences for Outdoor Temperature Categories – after Retrofit

Source: Author (2012)

5.5 Lag Analysis

The rate at which Indoor Temperature changes over time is another means by which to understand the comfort environment. Gradual temperature changes are favourable as they give occupants the chance to acclimatise over a longer period of time. Shear temperature changes are less favourable and compel occupants to correct the changes through adaptive behaviours, such as opening or closing windows, adjusting curtains or changing clothing.

5.5.1 Methodological Underpinnings

Intra Class Correlation (ICC) is a descriptive statistical technique used to determine the degree to which groups of quantitative data are related to each other. The approach is typically used to assess the agreement or consensus between data of two sets of independent raters (evaluators) on the same subjects. The effect of scale is included in the ICC measurement providing a measure of the degree to which the measurements of two or more raters are related (Stattools, n.d.).

The ICC methodology was used to determine the lag effect of Outdoor Temperature stimuli, i.e. the time it took for Indoor Temperature to match (or catch up with) Outdoor Temperature. Statistically, this would be associated with the highest correlation (i.e. strongest relationship) between Indoor and Outdoor Temperature, which is the vertex (or turning point) of the graph. The time lag associated with this point is subsequently discernable from the X-axis (Figure 5.6). Given that the data recordings were at 15-minute time increments, each unit on the X-axis represents this interval, e.g. a vertex corresponding to a lag of +3 would thus be associated with a 45 minutes lag between Outdoor and Indoor Temperatures.

Put another way, an ICC calculation implicitly computes how far forward one measurement must be taken in order to get the best fit with a corresponding static data point. In this case, keeping Outdoor Temperature constant and moving Indoor Temperature forward and backwards at 15 minute intervals, it can be discerned when Outdoor Temperature at Time 0 minutes matched up with the Indoor Temperature at 15 minutes, 30 minutes etc. and ascertained at what lag the two variables matched best, i.e. where Outdoor Temperature had caught up with Indoor Temperature.

5.5.2 Lag Analysis Results

The ICC results (Figure 5.6.1) are in line with the Indoor and Outdoor Temperature correlation results from Section 5.2, that is, in the order of most to least correlated: Control, Retrofit (before), Retrofit (after) and iShack. The vertexes of these graphs reveal that Indoor Temperature catches up with Outdoor Temperature after 15 minutes (at r=0.98) for the Control shack and similarly after 15 minutes for the Retrofit (before) shack (at r=0.97). Temperature parity results after 30 minutes for the Retrofit (after) shack (at r=0.92) and after 75 minutes for the iShack (at r=0.87).

On average, retrofitting an existing shack gave its occupants an additional 15 minutes to acclimatise to Outside Temperature changes, whilst iShack occupants had an additional 60 minutes over the Control shack occupants.

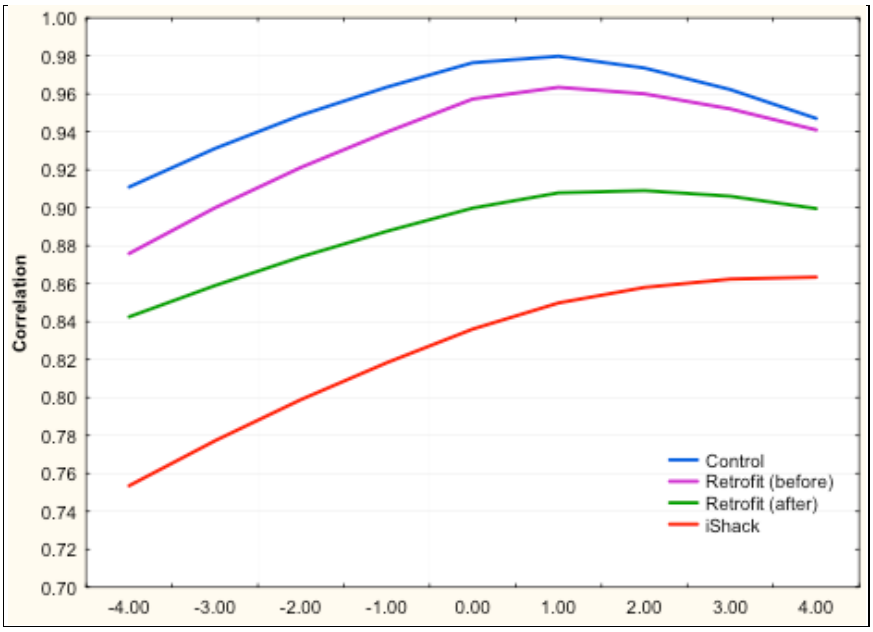

Figure 5.6.1: Intraclass Correlation Lag Analysis
Source: Author (2012)

5.6 Thermal Comfort

The analysis presented up to this point has given an indication of the thermal performance of dwellings, yet failed to link these up to the comfort of occupants. The methodology of Holm & Engelbrecht (2005) was outlined in Section 1.8.4 and used in calculating the thermal comfort performance. This was useful since the methodology "includes *adjustment* (behavioural/technological changes to heat balance), *habituation* (psychological adaptation, changing expectations), and *acclimatisation* (long term physiological adaptation to climate)" (Holm & Engelbrecht, 2005:11, italics original) that people take to adapt to their thermal environment.

The Dry Bulb Neutrality temperature (TnDBT) was calculated for every day using daily maximum and minimum temperatures with results confirmed to be within the 17,8°C < Tn < 29,5°C range. Subsequently, lower building quality comfort acceptability range (80%) was applied to TnDBT results, giving a thermally comfortable temperature range (±3,5°C) against which to plot individual time series data observations.

In Table 5.6.1, the results of the Thermal Comfort methodology are presented. The 'Percentage' column refers to the percentage of time that a given shack was thermally comfortable over the period under analysis according to the ±3,5°C stringency standard, whilst 'Time' is the percentage figure converted to hours and minutes. 'Difference' refers to the variance in 'Percentage' or 'Time' between various shacks. To gain an appreciation of the time periods when the shacks were within the thermal comfort range, daily Indoor Temperature Fluctuations were plotted alongside ±3,5°C Thermal Comfort bands for all shacks in Figures 5.7.1 – 5.7.3.

Table 5.6.1: Comfort Acceptability Range Result

	Percentage	Time
Control	28,27%	6h47m
iShack	48,06%	11h32m
Difference	*19,79%*	*4h45m*
Retrofit (before)	32,26%	7h44m
Retrofit (after)	47,19%	11h19m
Difference	*14,93%*	*3h34m*

Source: Author (2012)

From Table 5.6.1, it can be seen that on average, the Control shack was thermally comfortable for 6h47m (28,27%) every day and the iShack an additional 4h45m (19,79%) to result in an iShack daily thermal comfort proportion of 11h32m (48,06%). These trends are displayed graphically in Figures 5.7.1 and 5.7.2, which shows a significantly greater proportion of thermal comfort for the iShack. Furthermore, observable is the fact that Indoor Temperatures which fell outside of the thermal comfort range predominantly were at lower temperatures for both the Control and iShack. On average, retrofitting an existing shack had the effect of increasing thermal comfort by an additional 3h34m (14,96%) every day, evidenced by the increase from 7h44m (32,26%) for the Retrofit (before) shack to 11h19m (47,19%) for the Retrofit (after) shack. From Figure 5.7.3, this improvement is shown graphically in the form of greater Indoor Temperature movements within the thermal comfort range. In line with the Control and iShack's thermal comfort performance, relatively speaking, thermal comfort was greater during warmer temperatures.

Comparing the iShack and Retrofit (after) shacks reveals near identical thermal comfort performance – the iShack delivering an additional 13 minutes (0,87%). This would suggest that the act of introducing shack retrofits renders a near identical thermal comfort performance to that of a newly constructed shack, built in line with ecological and sustainable design principles.

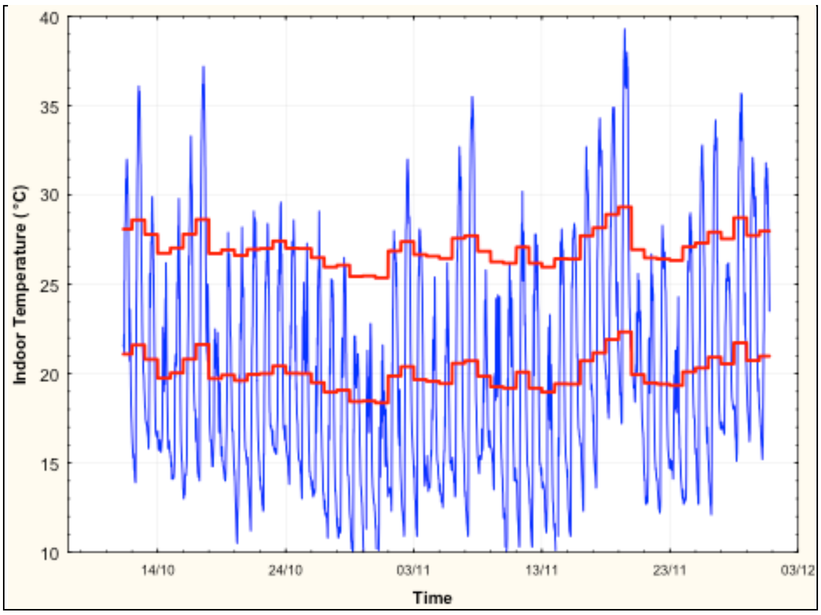

Figure 5.7.1: Control Shack Indoor Temperature Fluctuation with ±3,5°C Acceptability Band

Source: Author (2012)

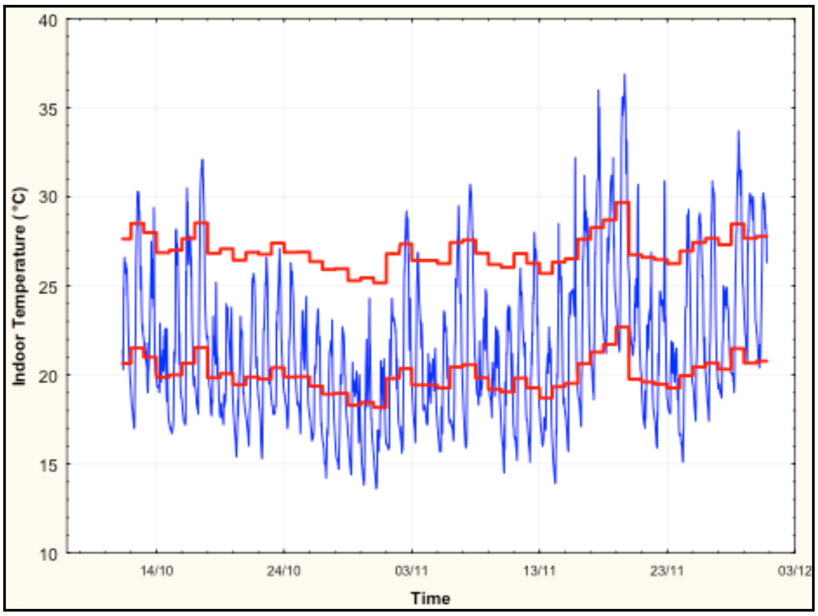

Figure 5.7.2: iShack Indoor Temperature Fluctuation with ±3,5°C Acceptability Band
Source: Author (2012)

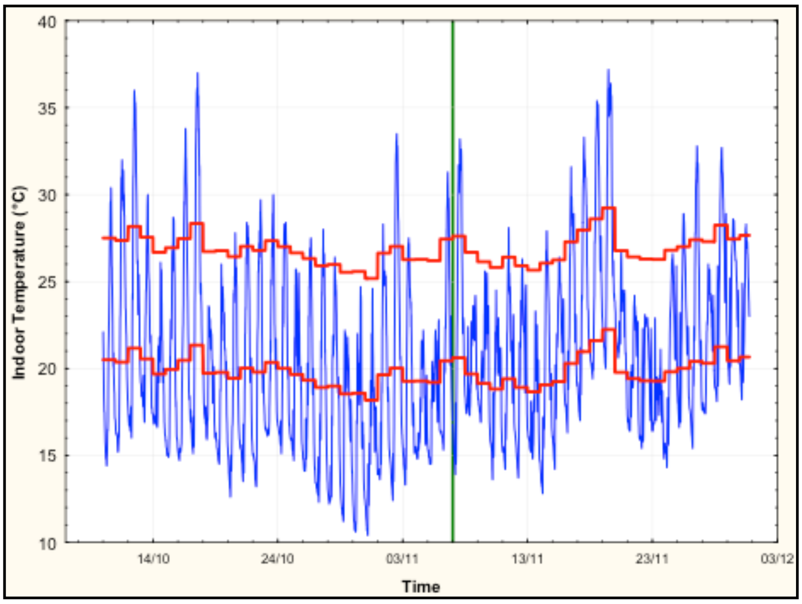

Figure 5.7.3: Retrofit Shack (Before and After) Indoor Temperature Fluctuation with ±3,5°C Acceptability Band
Source: Author (2012)

5.7 Key Results and Discussion

5.7.1 Key Results

Following, is a summation of the key statistics from above as they relate to the energy-poverty discussion. The iShack's thermal performance displayed a decoupling effect between Indoor and Outdoor Temperature since in comparison to the Control shack, the:

- iShack's Indoor Temperature Fluctuations were between 4,89°C and 7,22°C narrower on mild (<25°C) and hot (≥30°C) days respectively;
- iShack's Temperature Difference (buffer effect) between Indoor and Outdoor Temperatures was 5,75°C larger; and
- iShack's Indoor Temperature Changes took 60 minutes longer to respond to changes in Outdoor Temperature Changes.

The iShack demonstrated the greatest thermal improvement during cooler daytime temperatures and cooler days, since in comparison to the Control shack, the:

- iShack's Indoor Temperature difference was the largest during cool daily periods (01h00 to 06h00) by 4,05°C; and
- iShack's largest comparative Indoor Temperature difference was on mild days (<25°C) by 3,94°C.

Similarly, retrofitting an existing shack improved its thermal performance, since in comparison to the Retrofit (before) shack, the:

- Retrofit (after) shack's Indoor Temperature Fluctuations were 3,84°C narrower on mild (<25°C) and 1,25°C wider on hot (≥30°C) days;
- Retrofit (after) shack's Temperature Difference (buffer effect) between Indoor and Outdoor Temperatures was 2,81°C larger; and
- Retrofit (after) shack's Indoor Temperature Changes took 15 minutes longer to respond to changes in Outdoor Temperature Changes.

Furthermore, the Retrofit (after) shack also demonstrated the greatest thermal improvement during cooler daytime temperatures and cooler days, since in comparison to the Retrofit (before) shack, the:

- Retrofit (after) shack's Indoor Temperature difference was the largest during cool daily periods (01h00 to 06h00) by 2,73°C; and
- Retrofit (after) shack's largest comparative Indoor Temperature difference was on mild days (<25°C) by 3,57°C.

5.7.2 Energy-Poverty effect

Linking these results back to the energy-poverty discussion and fuel use, it can be seen that the thermal performance results attest to the efficacy of both a Retrofit and iShack intervention since both brought about significant improvements in the thermal comfort of occupants of between 3h34m and 4h45m per day respectively. The thermal performance of both the Retrofit and iShack interventions, whilst tempering the indoor climate during warm periods, were most pronounced during cooler time periods and on cooler days. In the absence of electricity, many households heat their homes with paraffin heaters or coal and wood fires (Figure 5.8.1), which have negative energy-poverty entrenching dynamics (as discussed in Chapter 2). A reduction in the usage of these fuels brings immediate and tangible relief to these households.

Figure 5.8.1: Wood-fired indoor heater – Enkanini
Source: Photograph by Author (2012)

Most of the benefits unlocked by these interventions are incommensurable and cannot be reduced to monetary or emission figures[39]. Indeed, this may form the basis of a future study, but goes beyond the ambit of this current work. For this the researcher relied on the informal feedback of the Retrofit and iShack occupants. Both households had been in a position to observe the changes in their shelter and energy situations in a short period of time – overnight. Feedback was recorded, transcribed and then included in summary of the salient thoughts on the interventions below.

Mthelo, the Retrofit occupant, reported the following:
"The retrofit is a good thing, my wife and I can feel the difference but also we have been looking at the computer inside [the data logger which presented Indoor and Outdoor Temperatures] and I can see it is warmer in the morning and the [Indoor] temperature is not going with the outside [temperature] that quickly. I didn't know if it was going to work because it is just cardboard and I didn't think it could make a difference. I think that tetrapak is working very well because the shiny side is pointing outside so it is sending the hot air and cold air back. The wind doesn't get inside anymore and when it's hot outside I open the window and it [the heat] can escape. My house is looking much nicer on the inside and I am going to keep improving it now. But first, I also need a solar system [DC Multigrid system][40]"

Plaatjie, the iShack beneficiary reported the following. In regards to the iShack: "My children were always sick in that old shack (Figure 5.8.2), it was always cold and the rain was [getting] inside and the wind was coming through the holes. It didn't have a floor, it was wet and muddy underneath. We were always cold and I also was sick often. I like the iShack because it is a nice and proper house. My friends come and visit me more now and I also have church meetings here now. The wind doesn't blow inside anymore, it's not wet inside. I feel comfortable. And my kids like it too."

[39] A first attempt at computing the monetary reduction by the DC Multigrid system was a recent study by Nelson Mandela Metropolitan University in Thembalethu (George, South Africa) which showed that the installation of solar lights alone, brought about a R76,50 monthly saving on paraffin (Loftus, 2011).

[40] Upon completion of the pilot, DC Multigrid systems were donated to the Control and Retrofit households.

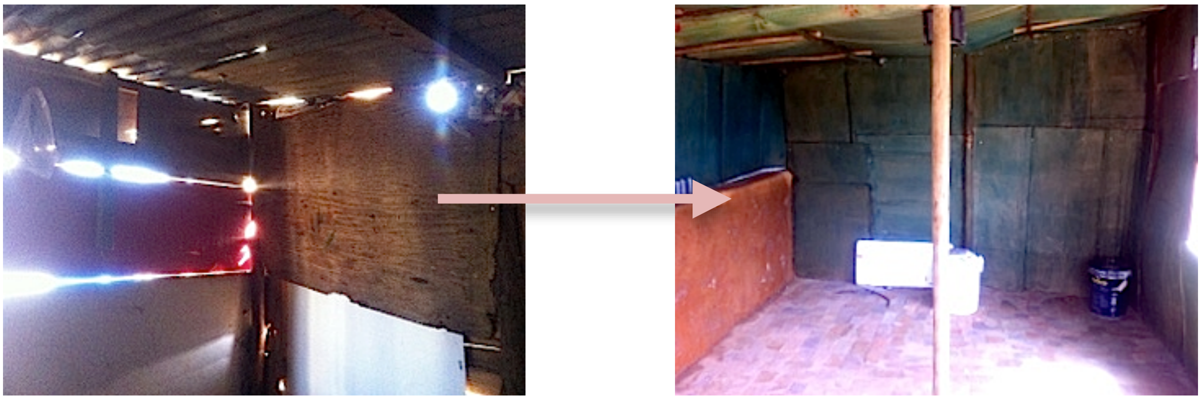

Figure 5.8.2: The Indoor of Plaatjie's original shack (left) and the Indoor of the iShack (right)
Source: Photographs by Author (2012)

Her comments on the DC Multigrid system were as follows:
"Before [I got] the solar [system] I had to go and visit my friend in Zone O [about 600m distance] where she had electricity to charge my old cellphone. I needed to wait for 4 hours. Sometimes my phone was flat for many days because I didn't know what to do with my children during the charging time because I can't carry them that far and it was too far for them to walk. It was difficult because I get phone calls about work and I [used to] miss them so people stop[ped] calling me. Now I am available all the time and it is helping me to make more money. Paraffin is bad and getting more and more expensive. Also candles are not good because they are dangerous and I always have to watch my kids. The solar [lights] are better. Now we don't need to go to sleep early anymore because now we have lights. My daughter must do her homework now, she doesn't have any more excuses. And I like the light outside because we can see what is going on, I feel safer".

The immediate socio-economic benefits of the interventions may be distinct for different householders. However, based on the feedback from the Retrofit and iShack occupants, the additional energy-shelter interventions held the potential to:

- Improve the economic standing of households through guaranteed mobile connectivity;
- Improve the health of occupants through reduced traditional fuel usage for space heating during cool periods;
- Have a positive impact on the education of child learners through the opportunity to study after hours;
- Improve social networks through a greater interaction with friends and churchgoers;
- Let occupants feel safer at night given the outdoor security light; and
- Encourage householders to invest further into their dwellings.

It is possible to draw direct causal linkages between these benefits and the energy-poverty drivers outlined in depth in Chapter 2. The simple, cost-effective energy-shelter interventions brought about direct, observable and far-reaching socio-economic benefits to the householders.

5.8 Conclusion

In this chapter, the target knowledge developed in Chapter 4 was validated through a statistical analysis of the thermal performance and thermal comfort performance of the Retrofit and iShack. Both shacks demonstrated reductions in Indoor Temperature fluctuations; an increased buffer effect to shield against Outdoor Temperature stimuli; and increases in the Lag Effect between Indoor and Outdoor Temperature swings. The interventions resulted in net improvements in thermal comfort of 3h34m and 4h45m per day for the Retrofit and iShack's respectively.

An analysis of the results, coupled with feedback from the project participants revealed far-reaching socio-economic benefits that included direct reductions in the level of energy-poverty at the household level.

In the following chapter, the energy and human settlements policy space will be examined in order to generate the transformation knowledge necessary to actuate these energy-shelter transitions.

Part C: Transformation Knowledge

"Transformation knowledge is about how to make the transition to the target status. This includes technical, social, legal, institutional and other changes" – (Hadorn et al., 2008 in Cronin, 2008:12).

Chapter Six: Enabling additional energy-shelter responses

6.1 Introduction

Target knowledge as it pertains to additional energy-shelter development responses was shown to deliver significant socio-economic benefits with poverty-alleviation characteristics for informal households. Transformation knowledge, necessary to action the transition towards target statuses, will be developed in this chapter through an analysis of the space within the energy policy (Section 6.2) and human settlements policy (Section 6.3) where incremental energy-shelter response opportunities exist, whilst a set of alternative funding options (Section 6.4) highlight the financing opportunities outside of the policy sanctioned subsidy environment. It was found that some latitude exists within the policy space to realise incremental transitions, yet in order to deliver meaningful and targeted benefits, a separate policy space needs to be created to cater for additional responses. Through a case study approach of the Thai Slum Upgrading programme (Section 6.6) and a canal-side community upgrade (Section 6.7), a first attempt is made at deriving a set of successful upgrading principles (Section 6.8) that could contribute towards addressing some of the shortcomings of the Upgrading Informal Settlements Programme (UISP) in its current form (Section 6.9).

6.2 Free Basic Alternative Energy Policy

The Free Basic Alternative Energy (FBAE) Policy was discussed at length in Chapter 2. Unelectrified communities that were unable to access the Free Basic Electricity subsidy could access a subsidised non-exhaustive list of energy carriers (including coal, paraffin, LPG and Bio-ethanol gel) through the FBAE subsidy. Municipalities are tasked with the implementation of the policy by identifying areas where energy-poverty is prevalent; that are most distant from the grid; and where there are no immediate plans for electrification or a solar home system program. Indigent households qualifying for FBAE are entitled to a minimum monthly allowance of R55 of energy – a figure that is subject to an annual adjustment of inflation plus 1,5% (DME, 2007).

Table 6.1: Free Basic Alternative Energy Monthly Calculation

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Inflation		11,50%	7,10%	4,30%	5,00%	5,70%	8,00%	8,00%	8,00%	8,00%
FBAE Increase		1,50%	1,50%	1,50%	1,50%	1,50%	1,50%	1,50%	1,50%	1,50%
Monthly	R55,00	R62,15	R67,49	R71,41	R76,05	R81,53	R89,27	R97,75	R107,04	R117,21
Annual Amt						R978,32	R1 071	R1 173	R1 284	R1 407
Cumulative Amt							R2 050	R3 223	R4 507	R5 914

Source: Author (2012)

In Table 6.1, the 2012 monthly FBAE allowance has been calculated and a future estimate calculated for up to 2016. Historical inflation rates were the average annual Consumer Price Index (CPI) derived from the Statistics SA website, whilst an average CPI of 8% per year was assumed for the forward estimate. From these results, it is evident that indigent households qualify for R81,53 per month in 2012 and within 4 years, this amount increases to R117,21 per month.

These figures may be applied to the R3625 cost of the DC Multigrid core unit (Chapter 3) in order to determine its access affordability. Assuming that the entire Monthly FBAE amount is allocated towards this system and ignoring the Time Value of Money, from Table 6.1 it can be calculated that the system would be paid off within 3 years and 4 months. Should grant funding be secured and/or households contribute towards monthly instalments, then the payment period would be drastically reduced. This point may be illustrated by an example. Consider that the funds which are normally spent on lighting gets invested into DC Multigrid repayments, a reasonable assumption given that the core system completely replaces the need for alternative lighting spend. From the informal interviews conducted in Enkanini (Chapter 3), it was discerned that Enkanini residents spent between R30 and R50 for lighting service per month alone, composed of candles (R2,50 each) and paraffin (R9 per liter). Using the average of the two figures of R40/month[41] (R10/week), the payment period from the core unit would be reduced to just 2 years and 2 months. The useful life of the system, including the battery (if used correctly) is far in excess of the repayment period, making aspects such as micro insurance of the system and microfinance available – since the time value of the underlying asset is important in these instances.

The FBAE policy has the potential to enable sustainable energy transitions, especially if coupled with supplementary sources of income in order to pay off the DC Multigrid system. What is required is for the financial, administrative and logistical bottlenecks, which are currently hampering the rollout of FBAE, to be resolved. These are necessary in conjunction with campaigns to raise awareness of the potential benefits of the policy as well as pilot projects to demonstrate the manner in which it can be implemented. Does the Human Settlements Policy hold a similar dedicated space for informal shelter improvements?

[41] A reasonable assumption given the recent research findings of Louw (2012) which reported that the introduction of DC Multigrid lighting entailed a R76,50 monthly paraffin saving for lighting service alone.

6.3 Emergency Housing Programme

Interim engineering services have long been accepted as a legitimate response to curb the depravity and vulnerability of informal communities, yet currently no dedicated mechanism exists within the Housing Subsidy Quantum that addressed the top structure of slum dwellers (Misselhorn, 2011). Currently, only through the Emergency Housing Programme (EHP) can sustainable and incremental shelter responses be explored, yet this depends on the interpretation of the definition of 'emergency' as well as the foresight of programme implementers.

The EHP is "designed to provide temporary relief to households in a state of exceptional housing need, living in unsafe conditions, or rendered homeless, through the provision of secure access to land, engineering services, and shelter" (HDA, 2012:16). As such, the EHP is currently the only housing programme that offers funding for the improvement of informal structures, to reduce the vulnerability of poor communities. The policy was designed to offer short to medium-term solutions to housing need to fill the gap between short-term disaster response interventions and longer term housing programmes (HDA, 2012). Interventions under the policy should weigh up the need for rapid emergency responses as well as longer term settlement plans and should in all circumstances attempt to find permanent housing solutions in line with other housing programmes, which might include the UISP, People's Housing Process, Community Residential Units, Social Housing, and others. According to the policy, both proactive and reactive emergency housing responses may be covered. Proactive approaches involve the addressing of hazardous situations before a disaster arises, thus mitigating or preventing the severity of a crisis. Reactive approaches involve responding to an emergency that has left people homeless or destitute. Municipalities, as implementers, receive funding from provincial government and may receive a provisional allocation for emergency situations if these are negotiated with the province and budget estimates are included in the Medium Term Expenditure Framework (HDA, 2012). In order for the EHP to be applicable, an emergency has to be proven, which the policy defines as follows:

"An emergency exists when the MEC [Members of the Executive Council], on application by a municipality and or the PD [Provincial Department], agrees that persons affected owing to situations beyond their control:

a) Have become homeless as a result of a declared state of disaster […],
b) Have become homeless as a result of a situation which is not declared as a disaster, but destitution is caused by extraordinary occurrences […],
c) Live in dangerous conditions […],
d) Live in the way of engineering services or proposed services […],
e) Are evicted or threatened with imminent eviction from land or from unsafe buildings […],
f) Whose homes are demolished or threatened with imminent demolition […],
g) Are displaced or threatened with imminent displacement as a result of a state of civil conflict or unrest […],
h) Live in conditions that pose immediate threats to life, health and safety […],
i) Are in a situation of exceptional housing need […]" (DHS, 2009:15).

According to the EHP, the definition of emergency is broad in nature, speaking to its core principles of rapidity and flexibility, with grant funding structured for easy dispatch and procedural requirements kept to a minimum (HDA, 2012). In order to capture all potential emergency situations, three broad response options are sanctioned under the policy, each with nuanced response sub-categories, namely 1) On-site assistance, 2) Relocation/Resettlement and 3) Formal Housing Repair. A decision-making flowchart assists in navigating through the complex decision making stages in order to determine the correct response in an emergency situation (Figure 6.1). The response options will be examined further save for Formal Housing Repair which, given the focus of this study, applies to instances where formalised shelter provision has already occurred and thus is not applicable to informal shelter improvements (HDA, 2012).

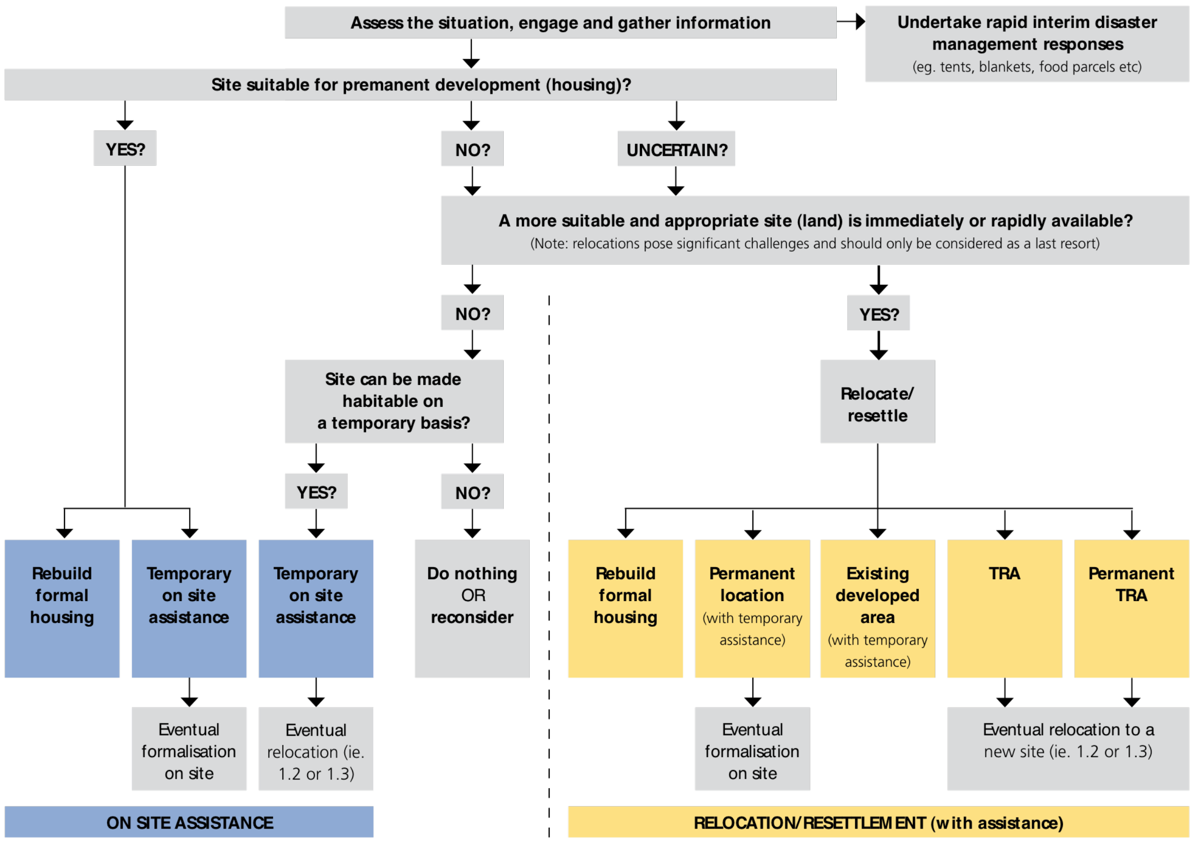

Figure 6.1: Summary Flowchart of Emergency Housing Situation
Source: HDA (2012)

6.3.1 On-site Assistance

On-site Assistance is appropriate in instances where no relocation is required, i.e. the site is suitable for permanent habitation and temporary housing assistance is the first step towards a permanent solution (Policy Category 1.1); or in instances where resettlement is necessary in future, however the site can be made habitable until such time (Category 3.2). This response category is most frequently used reactively to address events such as shack fires or flooding, however it lends itself well to a proactive approach to pre-empt emergencies in instances of high vulnerability, through measures such as re-blocking of shacks (by providing materials for improved building) and/or basic services. In terms of dwelling support or improvements, on-site assistance may take three forms, depending on the appropriate response:

a) *Starter Kits* – A package of materials (zinc sheets, timber poles, nails, plastic sheets) is provided directly to affected households who use these materials to rebuild their shacks and should be complemented by training. The quantity of materials varies according to the degree of devastation, funding availability and intended interventions (e.g. roof only).
b) *Contractor Built Structures* – Contractors may be appointed to repair existing informal structures or to construct a transit facility on site. The latter are often uniform structures of improved quality, may be prefabricated and should ideally be reusable.
c) *Re-blocking and Mitigation* – Re-blocking involves the spatial reconfiguration of shacks to unlock public space, provide road and basic services access thus decreasing vulnerability. Mitigation entails actions that improve the safety of the site for temporary or permanent habitation, e.g. constructing retaining walls or storm water channels (HDA, 2012).

6.3.2 Relocation / Resettlement

In instances where an emergency site is unsuitable for permanent development, relocation to a Temporary Relocation Area (TRA) may be fitting on a permanent or temporary basis depending on whether the TRA site is envisioned for permanent settlement (Policy Category 3.1 and 3.3). Alternatively, relocation to a permanent location with temporary assistance is appropriate, if permanent housing is earmarked (Category 1.2); or households may be resettled to an existing housing development area (Category 1.3). These responses are most frequently used in instances where, due to an emergency, a site is temporarily or permanently uninhabitable, requiring the temporary relocation or permanent resettlement of affected communities. More specifically:

a) *Relocation* – is appropriate on occasions where an emergency site is temporarily unsuitable for habitation but may be reinhabited at a later stage; or where affected people are temporarily accommodated elsewhere en route to a permanent housing solution.
b) *Resettlement* – is appropriate in instances where people cannot be included in an in situ upgrade due to space constraints, and need to be accommodated elsewhere; or where a site is deemed unsuitable for temporary or permanent habitation; or where evicted people need to be accommodated (HDA, 2012).

The most common shelter response for the Relocation / Resettlement category are TRAs, which may be constructed on a temporary or permanent basis, although the latter is not commonly used given the significant planning procedures that need to be adhered to. The City of Cape Town however has recently investigated more permanent TRAs and developed the concept of Incremental Development Areas (IDAs), which "… will enable the City to provide immediate relief to families that have fallen into desperate circumstances; and find a way of preventing isolated incidents from stalling progress with ongoing municipal functions" (CoCT, 2010:29). IDAs are intended to be located on land suitable for long term upgrading, that is, once their function has been fulfilled, i.e. the sites will never be cleared. IDAs may be regarded as residential transit areas e.g. for people waiting for RDP houses – as one group moves into their new homes, another group takes their place (CoCT, 2010), or to accommodate people affected by emergency situations.

6.3.3 Applicability to Energy-Shelter responses

In addition to the shelter responses discussed above, EHP funding may be used for the installation of temporary or basic emergency services such as water and sanitation, refuse removal and road access. In terms of energy services however, the EHP specifically dictates that electricity provision is not to be covered by the grant instrument save for the installation of high-mast lighting in exceptional cases (DHS, 2009). Energy interventions are to be covered through alternative funding sources, such as internal municipal revenues, energy infrastructure grants or energy subsidies. The National Norms and Standards for municipal engineering services should be considered as much as possible, but do not need to be adhered to under the EHP (DHS, 2009).

The two additional developmental responses on the stylised Energy-Shelter Trajectory may be applied to the interventions sanctioned under the EHP. During the *On-site Assistance* response, where shacks are being rebuilt or repaired, ecological design features, such as those of the iShack, may be included at no additional cost – the orientation may be corrected northwards, an overhang may be introduced, windows may be spaced correctly. The iShack is composed of a variety of sustainable and ecological design interventions, which are maximised if introduced together, however individual components may still be introduced in isolation and will render a good result. Herein lies a significant opportunity to improve the thermal comfort of shack dwellers regardless of whether they are self-built or commissioned by a contractor. The Guidelines to the EHP stipulate the fact that training should accompany the provision of starter kits, providing the opportunity to go beyond the mere reconstruction of shelter to address energy-poverty dimensions as well.

The interventions advocated in this study are especially applicable during proactive re-blocking exercises when shelters are demolished and reconstructed with improved materials and layouts. This is due to the benefit of time, since more resources can be invested into proper planning of site layouts and spacing and community training. Introducing elements which fall outside of the EHP grant funding, such as insulation materials, can be enabled through community savings activities which contribute towards shelter upgrades, thus capitalising on the momentum built up by reconstructions to maximise on aspects such as quality of materials used and the size of new dwellings. Savings is an inherent component of the SDI methodology when it comes to re-blocking, with households contribution, on average, 10% of the cost of the upgrade.

Perhaps the greatest possibility for energy-mindful shelter construction is available under the *Relocation / Resettlement* response, as it relates to TRAs. The EHP policy outlines minimum technical specifications which serve as guidelines for municipalities and provinces for the construction of TRAs, thus setting a relatively high standard of material quality. The policy stipulates that discretion can be applied in regards to material usage, size and design of dwellings as long as these minimum technical standards are adhered to, whilst the National Norms and Standards may be disregarded (DHS, 2012). Thus, significant policy sanctioned latitude exists in regards to the way in which the dwellings under this response can be constructed, since, the technical specifications are not in conflict with ecological and sustainable design interventions.

The EHP and FBAE thus hold the potential to enable energy-shelter transitions, however what alternative options are available to those slum dwellers that may not qualify for benefits under these two programmes?

6.4 Alternative Funding Options

Numerous other options are available to informal settlers over and above the outright government subsidies, in order to upgrade their shelter or energy infrastructure independently. These will be analysed at an increasing scale from the level of the individual slum dweller, to neighbourhood district to community scale, and correspond to an increasing administrative burden, costs and concomitant time frames.

The options for individual slum dwellers to receive formal access to finance from banks or financial institutions is limited given their inherent demand side constraints of insecure tenure, irregular incomes and often inability to afford loans (Rust, 2007). Individuals thus need to rely on personal revenue streams, funds borrowed from friends and/or family, or non-bank micro lenders, although the latter option often entails unfavourable terms. Co-operative structures, such as SACCOs (Savings And Credit Co-operatives) (see www.saccol.org.za/) are viable means by which informal settlers can access credit, which can subsequently be spent as they see fit. SACCO members pool their savings and make loans to each other at reasonable interest rates (SACCO, n.d.).

At a neighbourhood district scale, funding alternatives include a) grant money which starts a revolving fund that recycles individual or community loans, b) community savings that are matched with grant funding, and/or c) complete community funding with no outside assistance (SDI, 2007). Another variation is bridge financing, which enables the commencement of projects against a guaranteed back payment from e.g. a government source. Examples of these are the uTshani fund (see www.utshani.org.za/) which supports SDI's South African Federations and is specifically applicable to shelter upgrades, and The International Urban Poor fund (see www.sdinet.org/upfi/), managed by SDI and its global partners, which makes financing available to federations at a global scale.

Carbon financing becomes available at a programmatic scale. Emissions reductions against a baseline are inherent to the developmental responses advocated in this work, and if summated across a settlement can become sufficient to warrant trading on international carbon markets. Two examples will briefly be discussed as they entail varying sources of carbon finance:

a) Basa Magogo ('Light it up! Grandmother! in Zulu) is a behaviour-change programme developed by the NOVA Institute (see www.nova.org.za/) that teaches poor communities an alternative way to burn coal in stoves, in order to be more fuel efficient, lower emissions and reduce adverse health impacts. The emissions reductions were verified by the Gold Standard (see www.cdmgoldstandard.org/) and are traded globally as Voluntary Emissions Reductions (Carbon Neutral, n.d.).

b) The Kuyasa CDM project improved the thermal and energy efficiency of 2309 RDP houses in Khayelitsha (Cape Town) through retrofit installations of solar water heaters, ceilings and CFL (compact fluorescent light) bulbs. In so doing, the project is reducing 2.85 tons of greenhouse gas emissions per low-income house per year over and above the day-to-day energy (read monetary) savings that are realised by occupants (Goldman, 2010). The project was financed through the Kyoto Protocol Clean Development Mechanism.

6.5 Discussion

In spite of the dawning realisation of the permanency of informality in national policymaking spheres, the policy terrain is still characterised by the glaring absence of a mainstream Human Settlements Programme that actively engages with informality. It would thus appear that, save for the few imminent turn-key housing recipients, the vast majority of South African slum dwellers will have to continue to rely on their own creative energies and financial resources to deliver their constitutional right to adequate shelter themselves.

The EHP is the only space within the current human settlements policy where sustainable shelter transitions can be realised as additional increments along the stylised Energy-Shelter Trajectory. Funding under the programme is available for those in 'exception housing need' which meet the definition of an emergency, as quoted above. It could be argued that many informal settlements meet this definition of emergency, and indeed disagreements between municipalities and provinces (which release the funding) on this exact point is not uncommon (HDA, 2012). However, given the limited funding available under the programme, the prioritisation of the most needy informal settlers and the predominant focus on formalised human settlement development, it can be concluded that the EHP is not a sufficient policy response to meet the intention of facilitating additional energy-shelter transitions prior to formalised housing provision.

At this particular juncture in the discussion, it may be useful to pause and reflect on the original research objectives that were determined in Chapter 1. Evident is the fact that Research Objectives 4 (*Identify spaces within the human settlements and energy policies that could support sustainable energy and shelter improvements)* has now been addressed.

6.6 Case Study: Baan Mankong

Given the lack of human settlements policy space to actively engage with informality, what is needed is a dedicated policy instrument that effectively and equitably expedites measures that improve the shelter conditions of slum dwellers whilst they are still living informally. The previous discussions demonstrated that, if done correctly, these alternative measures could hold the key to unlocking energy-poverty alleviating benefits through improved shelter construction and design. Inherent in the UISP programme and the BNG policy was a paradigmatic shift in the approach to informality through the conceding of the principles of a) situated development (in situ) and b) piecemeal improvements over time (incrementalism). However, as seen in Chapter 2, the inflexibility of the heavily prescribed processes under the UISP, the dependency on phased funding release and the insistence on exceptionally high Norms and Standards (amongst others) converged to diminish these progressive underlying principles. Whilst pioneering in principle, the implementation design is flawed.

A more flexible, responsive and inclusive approach to addressing informality in South Africa is required in order to be effective, and may make provisions to include the sustainable shelter transitions advocated in this study. Devising new policy precepts is beyond the scope of this work, however, the principles that may inform such a policy iteration will be developed in the remainder of this chapter through a case study approach. The Thai version of the UISP, called The Baan Mankong programme, as well as the Bang Bua community upgrade (implemented under the programme) will form the basis of the ensuing discussion.

The Government of Thailand initiated two new programmes in January 2003 to address the housing shortage, living conditions and lack of tenure security of its slum communities. The first programme was *Baan Ua Arthorn* ("we care"), which focused on the construction of new ready-to-occupy housing units on a rent-to-own basis for people that could afford US$23-37/month rental payments. The second was the *Baan Mankong Community Upgrading Programme* (Baan Mankong) which involved the channelling of state funds directly to communities via the Community Organisations Development Institute (CODI). A public institution of the Ministry of Social Development and Human Security, CODI enables communities to plan and carry out housing and basic services improvements themselves. Baan Mankong forms the basis of this analysis (Boonyabancha, 2005).

6.6.1 Baan Mankong Methodology

Under the oversight of CODI, Baan Mankong ("secure housing") funds are channelled directly to organised communities in the form of soft loans and flexible infrastructure subsidies, which finance collectively planned improvements in housing, environment, basic infrastructure and tenure security (ACHR, 2009).

Planning upgrading activities under Baan Mankong occur at a city-wide level through the creation of a network of communities, local government and other stakeholders which collectively plan a city-wide upgrading strategy. Key steps in the institutional organisation which give rise to this collective strategising and upgrading emerge out of the following processes:

- The design of a city-wide upgrading programme commences with meetings between networks of community organisations, which may include exchanges from other cities, as well as municipal staff.
- A joint committee is established, comprising poor community and network leaders, local government officials, academics and NGO staff, which play a central function in a) building new relationships, b) integrating upgrading projects into the city's development master plans, c) creating mechanisms to resolve future housing projects, and d) implementing upgrading

projects. The joint committee furthermore communicates progress reports and information pertaining to upgrading projects to community representatives at city-wide meetings.

- All slum communities are enumerated through surveys where information on household demographics, tenure status, infrastructure problems, savings initiatives, community organisations and existing development is populated. The surveying process serves two purposes: Firstly, to accumulate accurate information with which to develop a city-wide upgrading plan, and secondly, to establish new inter and intra-community linkages since the skills derived through an enumeration process are shared by enumerated communities with communities that have not been surveyed yet.
- Upgrading initiatives are integrated into city-wide development plans requiring coordination between public and private actors around issues such as land ownership, tenure and resettlement strategies, and community infrastructure utility grid integrations amongst other upgrading processes.
- Existing community savings activities are supported or new savings initiatives are created. These are mobilisation tools intended to leverage community resources and build management skills which are useful for the later management of upgrading projects.
- Community networks are established around the principle of collectivity. This is reflected through common land ownership, cooperative[42] enterprises, joint construction projects, community welfare and shared maintenance activities.
- Pilot projects are selected according to a set of criteria and are intended to serve as learning centres for all stakeholders.
- Homeless and migrant workers are identified and integrated into the improvement processes thus incorporating everyone into an upgrade.
- Continued exchange visits are organised between projects and cities for all stakeholders (Boonyabancha, 2005).

Collective processes are the bedrock of the Baan Mankong upgrading programme which are encouraged through the stipulation of the following conditions:

- “the upgrading has to include everyone in the community – rich or poor, renters or owners;
- wherever possible, the land tenure (lease or sale) should be collective;
- the upgrading work should be planned and implemented collectively;
- the housing loans are given collectively, to the community cooperative, not to individuals; and
- the social systems that are part of the upgrading are collective” (Boonyabancha, 2005:42).

6.6.2 Upgrading Typologies

The Baan Mankong programme recognises the heterogeneity of circumstances which poor communities face and subsequently grants significant latitude in the way in which projects are

[42] According to the International Cooperative Association (ICA), a cooperative is defined as “… an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise” (ICA, n.d.).

designed and implemented. Matching projects to the precise community contexts leads to greater success by ensuring household affordability of upgrading measures and minimising disruptions (e.g. relocations). The diversity in approaches (see Figure 6.2) is evidenced by the following upgrading examples which are derived from Baan Mankong pilot projects:

a) *Land Purchase and Re-blocking* – The Charoenchai Nimitmai community cooperative structure purchased public and privately occupied land at a competitive rate (a quarter of market value) and used a CODI loan to finance the purchase. Cost-per-family was reduced through a re-blocking exercise, where densities were increased through plot reshuffling creating space for further family's to relocate to the settlement.
b) *Post-disaster reconstruction and long-term lease* – a disaster is used as a catalyst for upgrading. In the instance of the Bon Kai community, where 200 houses were destroyed in a fire, a community cooperative negotiated a 30-year lease from the government ensuring tenure security, since conventionally, land leases are with individual households for shorter time periods leading to tenure insecurity. Upgrading commenced in 3 phases to prevent relocations during the construction of the three story row houses, which allowed all residents to be accommodated.
c) *Relocations* – communities which are settled on land that is unsuitable for habitation (e.g. pollution, chemical exposure, landslide risks etc.) negotiate collectively for alternative land in close proximity via a community cooperative structure. The relocation sparks off an upgrading exercise.
d) *Agglomeration* – an upgrading project sparks off upgrading activities in neighbouring community. Joining forces, by developing a master redevelopment plan, unlocks economies of scale through increased bargaining power and reduced costs. Land is leased through cooperative structures and a mixture of relocations, reblocking and densification allows for higher densities further driving down costs.
e) *Land Sharing* – communities located on privately owned land, successfully negotiate the purchase of a small portion of said land via a CODI loan and vacate the rest of the property through the development of the now communally owned land (Boonyabancha, 2005).

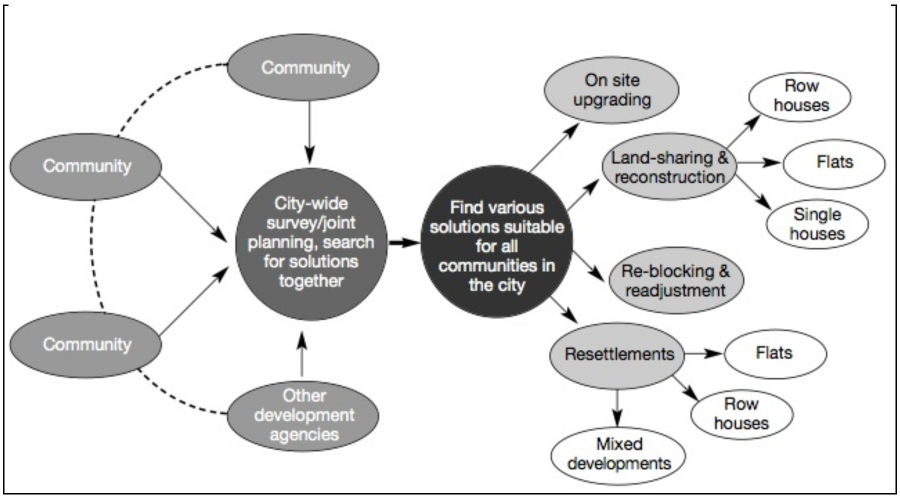

Figure 6.2: City-wide network of stakeholders find solutions entailing various housing typologies
Source: Boonyabancha (2005)

The average cost per household including construction, infrastructure and land purchase (in US$ 2005) for the pilot projects mentioned above ranged between US$4901 and US$9039, with monthly household repayments of US$22-50. Pilot projects were selected according to the criterion of households with monthly incomes of under US$250, demonstrating the ability and willingness of even the poorest slum dwellers to contribute their meagre earnings to living in improved conditions. Tenure security, which enables upgrading to commence, allows for the creation of a real asset that is transferable, subject to capital appreciation, and encourages further household investments into improvements.

The project typologies furthermore demonstrate that a blend of outright purchase and/or long-term renewable lease are viable means in which to secure tenure, whilst relocation and/or re-blocking can be deployed as densification strategies that can increase public space, reduce cost and improve land conditions.

6.6.3 Governance and Oversight

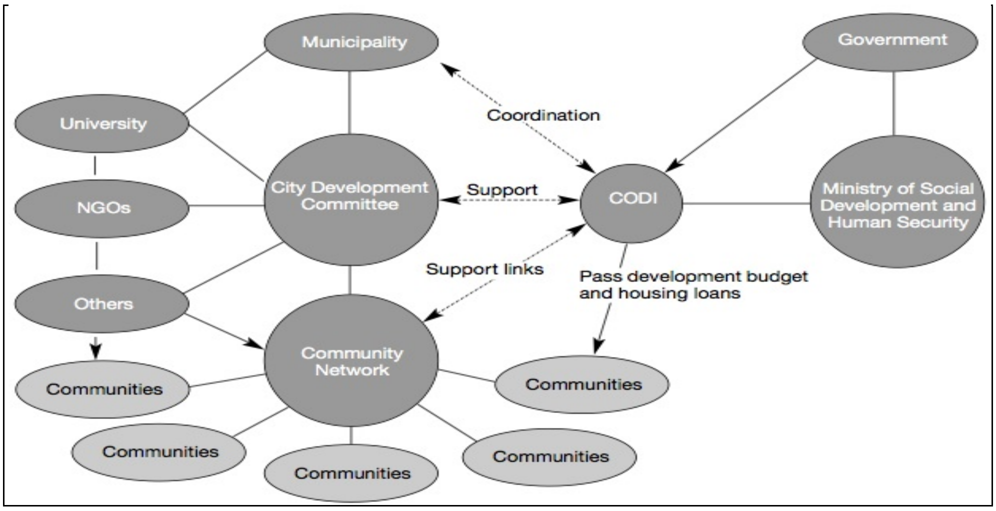

Figure 6.3: Baan Mankong Programme Mechanism
Source: Boonyabancha (2005)

A web of support organisations, networks of stakeholders and government partnerships enable community-led upgrading under the Baan Mankong programme. The mechanism, linkages and resource transfers are outlined in Figure 6.3. A community upgrading process can be kick-started in a variety of forms, such as a surveying tool (highlights pressing needs), a natural disaster or community exchanges.

Coordinating activities at a citywide scale can be challenging with hundreds of diverse slum settlements spread out across the city. The Baan Mankong programme deals with the issue of scale by creating 'cities within cities', that is, treating each city distinctly as a city within its own right through the formation of a dedicated joint committee, surveying tools and three year upgrading plan. Decentralising upgrading support actions within cities in this manner is not only an effective management tool, but also a way in which under-resourced municipalities can 'outsource' certain key responsibilities to communities. This governance structure can be mobilised to action community led maintenance of public parks, cleaning of drainage canals, recycling and waste management and community welfare programmes – all set into motion through an upgrading process – an active citizenry composed of the urban poor working in partnership with city authorities to manage collective spaces and infrastructures (Boonyabancha, 2005). At the community level, upgrading is managed in cooperative structures. This is a means of aiding decision making, increasing the credibility of communities and strengthening their bargaining power.

The financing arrangements under the Baan Mankong programme are a way in which the Thai government cedes significant powers to communities themselves to create the kind of settlements they would want to live in. The autonomy over financial budgets, administered by CODI, gives communities the freedom to design their own upgrading programmes and ensures that the significant infrastructural investments that poor communities have already made are incorporated as much as possible. The finance granted under the programme is flexible with the imposition of as few conditions as possible and no stipulation of physical outputs (Boonyabancha, 2005).

6.7 Baan Mankong Application: Klong Bang Bua

6.7.1 Background

> *"If it is just physical upgrading you're doing, the whole project can be finished in a few days. You don't need to do much work, you can just send in a contractor to do it. Their [the community's] capacities won't be changed. Their financial systems won't be changed. Their relationships won't be changed. Their land tenure insecurity won't be changed. It will still be a poor, vulnerable, marginalized and unorganized group of people who happen to live together in the same slightly improved squatter settlement. And two years later, they might still find themselves being evicted. That's not upgrading. Upgrading means a lot more than that"* – (Asian Coalition of Housing Rights, 2008:10).

Klong Bang Bua (*klong* means canal in Thai) is composed of a network of 12 informal settlements along a 13 kilometer stretch of one of Bangkok's major canals. Approximately 3400 families of low-income daily wage earners such as street traders and labourers have lived there for over a century. Bang Bua was the first community of canal-side dwellers to have successfully negotiated the lease of public land for its redevelopment – in this case, a 30-year renewable lease from the Public Treasury. Significant bargaining power through the backing of a citywide network of 200 other canal-side communities meant that the community was able to settle on reasonable terms – rental of 1Baht/m^2, inflation adjusted every 5 years. This translated into a monthly land rental payment of 30-70Baht (<US$3) per household which is collectively paid to the Treasury Department through a cooperative structure.

6.7.2 Mobilisation: Getting Started

> *"The network system is the main mechanism for poor people to link together and help each other. 'People to people' is the main mechanism"* – (Asian Coalition of Housing Rights, 2008:10).

Concerned about the deteriorating state of the canal water that had become black and polluted 15 years prior, a network of community representatives was established in order to coordinate activities to clean up the canal. Community elders remembered a time when the canal water was teaming with shrimp, clams and fish and when potable water was sourced from it. The environment, which connects all citizens, became a shared focal point giving rise to collaborative and institutional structures that could be dispatched for other shared concerns, such as the greater upgrading of the settlements (ACHR, 2008).

Initially, there was scepticism about the possibility of upgrading the Bang Bua communities as a Baan Mankong project. The communities felt that too much had already been sacrificed in existing investments and people were hesitant to take on any housing debt, even at favourable terms. These perceptions changed when poor communities started linking together through networks that emerged naturally from exchanges with other settlements. People were inspired by new possibilities which they automatically started to discuss and implement at home (ACHR, 2008).

6.7.3 Governance

Managing an upgrade project of 3400 households is a challenging task. The Bang Bua communities employed a small group management system, which divides 12 community cooperatives into groups of 5 households. These community cooperatives negotiated their own contracts with CODI and have their own leases. Decentralising decision-making in this manner places agency at the doorstep of every household, ensures a transparent and democratic process, unlocks the creative potentials of the community and effectively deals with stubborn residents that may be resistant to the upgrading process. The household groups selected their members themselves (typically relatives or friends) and began designing (with the help of architects), saving and upgrading when they were ready. Constituting household groups in this fashion builds on existing relationships of mutual affinity and trust and is useful during the challenging negotiations about plot exchanges in the upgrading process. Friends and families may thus stay together after a re-blocking exercise (ACHR, 2008).

A wider network of collaborating professionals, academics, NGOs and local governments support the upgrading activities of community cooperatives under the Baan Mankong programme. The Thai government channels subsidies to CODI, which acts in an intermediary and administrative capacity. Budgets are passed on directly to organised communities after being vetted by a committee of community leaders and developmental partners including city community networks and local authorities. Having autonomous control over their budgets strengthens organised communities and extends the benefit of upgrading over and above the physical domain – it builds capabilities (ACHR, 2008).

6.7.4 Communal Upgrading

> *"Savings gives people the freedom to do their own development. It's a kind of political system by people themselves – and it's working!"* – Lek Sompop, community organiser at CODI (ACHR, 2008:6).

The canal-side was connected by rickety 1m wide walkways which were a hazard for pedestrians and did not allow access to essential services, such as fire engines. Enlarging these was one of the primary foci of the Bang Bua's upgrading initiative, and the community did not wait for government approval to commence with the upgrades. Government standards required a width of 8 meters (4 meters each side) for canal-side lanes, which would have left almost no space for the construction of houses. Furthermore, constructing homes according to government regulations would have caused further delays. In the words of Khun Prapaat, a canal network leader, "Don't just wait for permission. Fight for permission later, when you have momentum on your side. If you ask, they will say. "*No way! That's illegal! That's substandard!""* (ACHR, 2008: 6, italics original). When threatened with arrest for disregarding a District Authority injunction to cease constructions, all 228 community members marched to the local police station and voluntarily offered themselves up for arrest. This determination and the evidence of successful, 'sub-standard' upgrading, changed the perceptions of, and relationships with, city authorities. The District Chief now invites communities to visit him and the District Authority, which now grants permission for upgrades, seconds its district engineer to assist with planning and structural designs. What is more, the district agreed to share the cost of the concrete walkway construction on reclaimed land. The community built the inner 2 meters, financed out of their own savings, and the district constructed the outer meter as well as railings and stairways down to the canal (Figure 6.4). The 3 meter lane is large enough for fire engine access, yet is not intended for motorised transport. Instead, street vendors now have a safe space to ply their trade, and children can play in a safe open space which has been planted with trees and flowers.

At a domestic level, each home in redeveloped communities was fitted with an individual septic tank that treats toilet wastewater prior to its discharge into the community's main drainage system. Kitchen grease filters were produced locally at a cost of 300Baht (US$8) and cleanse dirty kitchen water. The remaining grease is turned into candles. A community-wide water treatment facility treats grey water from connected household kitchen, toilets and septic tanks. This water is used for the irrigation of trees and only the excess of perfectly cleaned water is reintroduced into the canal.

Figure 6.4: The Bang Bua Canal before (left) and after (right) upgrading
Source: ACHR (2008)

6.7.5 Housing Upgrades: Typologies & Building

Three basic housing typologies were collectively developed by the Bang Bua community, namely a detached house, a semi-detached house and row houses, offering at least 90m^2 each of living space with sufficient space on the stand to access sewer pipes. The community built their homes themselves and a proper system managed the purchase of materials, construction process, division of work and the amount of construction input by owners. A prescribed daily rate of 250Baht was paid for skilled labour, and 220Baht for unskilled labour which was paid out of the Baan Mankong programme for infrastructure components or the household construction budgets of individual families. Almost all skilled and unskilled labour was sourced from within the community ensuring the revitalisation of the local economy and the emergence of a new generation of skilled construction workers. During construction periods, which typically lasted 3 months, temporary shelter was provided in simple one-roomed 'knock-down houses' made from zinc, plywood and timber and erected on the construction sites themselves or on whatever space could be found in close proximity. These temporary shelters were financed out of a CODI subsidy at a cost of 18 000Baht (US$520) each (ACHR, 2008).

6.7.6 Financing

Most members opted to take out a loan from CODI which was repayable over 15 years with monthly instalments of ±1 000Baht (US$30). This was affordable to most people, given that households with two incomes earned on average 15 000Baht (US$425) (up from 6 000Baht (US$175) per month ten years ago). Those that couldn't afford personal contributions or did not want to make use of the financing options that CODI made available typically made use of a high proportion of recycled building material content as well as any funding they could source elsewhere. Through the building of rental rooms (owned by the community cooperative) upgrades also catered for renting families that did not have structure-owner rights. The communities decided that the renters would qualify to build their own homes after having lived and rented there for 10 years. A communal *Baan Klang* (welfare house) was constructed to house the elderly and disabled who did not have anyone to look after them, and to house those in need in the future. In this way, all community members were included in the upgrading process (ACHR, 2008).

6.7.7 Welfare

The benefit of enumerating communities is the power of information to lobby government and to address certain key aspects within the community that require attention. The Bang Bua communities collectively decided to provide welfare benefits to those in need, through the formation of a welfare fund out of their own savings. The community cooperatives take out loans from CODI at a rate of 2% per annum and on-lend to families at a 6% rate. The revenue generated by this interest rate spread contributes to the welfare fund and assists those members that are having difficulty in repaying their loans. The fund pays the school fees of poorer children which also have access to tuition classes and libraries within the communities. A children savings group, which encourages the saving of 5 Baht per day, teaches children the benefits of collective saving, whilst another children's club organises camping trips nearby. The elderly are invited to all ceremonies, events and processions and a doctor comes on a monthly basis to tend to their healthcare needs. The welfare fund also provides burial assistance (10 000 to 20 000 Baht) to pay for coffins, flowers and ceremonies.

6.8 What constitutes a successful upgrade?

The key lessons from the Baan Mankong programme and Bang Bua community upgrade will be extracted in the ensuing discussion in order to populate a list of key principles that ensured their success, namely collectivity (Section 6.8.1), flexibility (Section 6.8.2) and incrementalism (Section 6.8.3).

6.8.1 Principle #1: Collectivity

Collectivity is the cornerstone of the Baan Mankong Programme and was a recurring theme during the Bang Bua upgrade. The principle speaks to higher ideals of equality, inclusivity and representation whilst on a more practical level enables decentralised management, encourages new partnerships to be formed, unlocks community creativity, ensures holistic upgrading and economic efficiencies to be realised. These collective benefits warrant further analysis:

a) *Representation through decentralisation* – Approaching upgrading from a collective approach ensures that divergent interests are properly understood and incorporated into the upgrading process (Cities Alliance, n.d.). The case studies demonstrated concentric hierarchies of household clusters which composed community cooperatives that linked into city-wide networks of slum dwellers – all working towards the same objectives. This system ensures representation of the individual who can effectively influence the wider upgrading agenda of an entire city. The small group management system employed by the Bang Bua Community was an effective means for thousands of households to organise themselves, ensuring that all opinions were heard, whilst the decentralisation of perfunctory administrative functions (which are resource intensive) to the level of the household (which take great care, interest and pride in being involved) decreased administrative costs.

b) *Building Partnerships* – The highly complex nature of upgrading and the requirement of complicated and varying information inputs can be assisted by the support of a range of dedicated partners (Cities Alliance, n.d.). Whilst a community such as Bang Bua may endeavor to draw on its own internal resources to expedite basic upgrading, only so much can be achieved – toilets still need to be connected to city sewers, safe buildings require architects and safe electrical installations depend on utility companies. A wider network comprised of local government, utilities, academic institutions, support NGOs and other communities creates a mechanism to solve current and future upgrading challenges. Building on prior successes through the institutionalisation of shared learning develops enormous capacities to support upgrading within the wider network of informal settlements, and provides a platform for other communities to join. Building relationships with local government allows upgrading activities to be integrated into wider city development plans.

c) Unleashing latent creativity – Upgrading perturbs the system status quo which brings about new conditions, problems and challenges. "How will people live together as a group, how will they help each other, how will they manage the land that is now owned by the community organisation? How will they collect money from everybody in such a way that people in sub-groups can assist each other? Or how will they manage to ensure they can make the loan repayments – which are collective repayments – when some individuals have problems or default on their payments?" (Boonyabancha, 2005:41). Collective processes stimulate discussions and problem-solving which inevitably inspire creative solutions to some fundamental problems.

d) Holistic and integrated – Effective upgrading needs to integrate social, environmental and economic aspects of a settlement in full cooperation with the communities (Rojas, 2010). Settlement upgrading should leave nobody behind, something that is stipulated in the Baan Mankong programme and was evidenced in the Bang Bua community, which used its own community savings to establish welfare functions for the elderly and disabled, create communal amenities such as libraries, and extended favorable financing to those in need. Hiring unskilled labour from within the community built capacities which could be employed for productive use post-upgrade elsewhere. A collective process ensures that the precise needs and priorities are elucidated and that upgrading programmes are designed accordingly.

e) *New system dynamics through scale* – Individual households or even clusters of concerned slum residents do not have the power or resources to effectively influence the developmental activities necessary to bring about desired changes in their communities. Collectivity is a means of amplifying the power and possibilities of communities through increased bargaining power and economies of scale.

How do communities organise themselves in order to upgrade? And what kick-starts a collective upgrading process? The following are key mobilisation tools of the SDI Alliance, which the Asian Coalition for Housing Rights (a support NGO of Bang Bua) is a part of:

1) *Savings schemes* – The formation of community savings collectives organises communities into manageable groupings which meet regularly, keep the upgrading objectives in sight and save

towards upgrading initiatives themselves. The savings collectives often become the selfsame scale at which communities organise themselves for upgrading. In Sheffield Road (Cape Town), savings was conducted at the level of clusters of 15 households whilst in Umlazi (Durban) the community was divided into 5 sections. Through an open and transparent process, community savings are a means to develop trust within the community (Bradlow, 2011a).

2) *Enumeration* – Surveying a community in its entirety can elicit valuable information by a community about itself, highlighting its precise developmental needs. Every household is surveyed by a trained community enumerator, which in itself sparks off momentum across the whole settlement – "something is happening". Building on local knowledge and capacities allows informal settlers to prioritise, plan and direct the focus of local upgrading activities (Bradlow, 2010b).
3) *Exchanges* – Nothing can inspire community members more than seeing successful upgrading projects on the ground elsewhere. Through exchanges between communities to pilot projects across cities and regions, new communities are inspired and an ever increasing network of urban poor communities is formed which can be drawn from for support.

The Bang Bua cases revealed that *Natural or Manmade Disaster* can also be a catalyst for communities to join together to collectively undertake an upgrade.

6.8.2 Principle #2: Flexibility

Informal settlements are not homogenous regions and house a high concentration of diversity – rich and poor people with different cultures and values. To treat settlements in a uniform fashion is doomed to fail since this does not provide the necessary room to incorporate those aspects which are essential to the wellbeing and comfort of resident in the context of their environment. Flexibility is thus a core principle by which to approach an upgrading project in terms of design and finance.

a) *Design* – Stipulating physical outputs curtails community creativity and resourcefulness through the adherence to externally predefined deliverables. A transparent and collective process has an inherent accountability instrument built into it which ensures that the use of available resources is maximised. The Baan Mankong programme does not prescribe precise physical outputs allowing communities to design upgrading projects which are most suitable for them. The benefit of flexibility allows for a more situated developmental response and ensures a higher level of acceptability. More specifically, the flexibility through the following design elements and considerations can significantly contribute towards successful upgrading:
   i. Relaxation of Norms and Standards – Although intended to ensure the equal delivery of quality infrastructure and housing with reduced maintenance requirements, norms and standards have the tendency to impede community-led upgrading programmes by adding undue costs, time frames and constricting expert opinions. Proponents of increasing housing regulations will argue that the economic provision of housing and infrastructures is dependent on standardised procedures and products. Yet, this centralised supply-side focused approach leads to increasing mismatches between people's housing priorities and the products they receive (Turner, 1991). Authorities can assist communities with those

aspects that residents have trouble with, e.g. foundations, stairways, bathrooms etc. (Rojas, 2010).

The Bang Bua community commenced with what would have been illegal road constructions without approval and in contravention of regulations, yet succeeded in demonstrating the satisfactory nature of the upgrade to such a degree that District Engineers now collaborate on similar 'substandard' projects.

ii. *Typological Variety* – Given the diversity of slum residents and the requirement that everyone is included in an upgrading project, the dwelling designs must be flexible enough to accommodate all residents – large and small families, migrant workers who prefer to rent, the disabled and elderly who need caretaker facilities and a range of income levels (even in informal settlements). Furthermore, in the Bang Bua case, allowing for flexibility in material usage to a certain degree, ensured that all residents are able to be accommodated, even the poorest, who would salvage materials from their existing structures or find new materials elsewhere. In this way, upgraded settlements become vibrant, creative settlements where everybody's shelter needs are met[43].

b) *Financing* – Controlling budgetary allocations is the most powerful means by which communities can shape the settlements that they would like to live in. In the instance of Baan Mankong, CODI channels funds directly to communities once upgrading plans have been finalised, ensuring funding autonomy at the grassroots level. The key lessons and skills necessary to manage finances for an upgrading project are acquired through group savings activities where communities learn democratic governance and teamwork and the management of funds through their administration and bookkeeping (SDI, 2007). "If a community cannot manage money, it is doomed forever to having its development process determined by someone else" (Boonyabancha, 2005:45).

6.8.3 Principle #3: Incrementalism

Incrementalism as a method of settlement upgrading is an approach inherently adopted by slum dwellers who, given their resource constraints, can only make small, piecemeal and cumulative improvements over time. Besides government policies that stymie post-upgrade incremental improvements, tenure insecurity is the major threat to incrementalism (Bradlow, 2010a).

a) *Tenure* – In the case of Baan Mankong, flexible tenure arrangements meant that communities could decide on a blend of outright purchase and/or long-term renewable leases. The Thai preference for land ownership is collective, whilst in South Africa individual freehold title is the mainstay of its housing policies, as enforced by the UISP. Yet, numerous alternatives tenure arrangements exist alongside these two options which can be seen as increments along a progressive tenure trajectory. The Global Land Tool Network has developed a tenure continuum

[43] Turner (1991) speaks to these two design aspects (Norms and Standards Relaxation and Typological Variety), through his postulation of the two 'controlling principles' of *Equifinality,* "the systems-term for the multiplicity of routes to the same end", and *Requisite Variety* "if stability (of a system) is to be attained, the variety of the controlling system must be at least as great as the variety of the system to be controlled" (Turner, 1991:31-32).

with a range of tenure possibilities between informal and formal land rights (Figure 6.5). Each intermittent step (which does not necessarily have to be consecutive) offers a different set of rights, responsibilities and degrees of security (Lemmen, 2010). Communities should endeavour to incrementally secure their land rights on their current location, or look at alternative forms of tenure which may be more suitable to the governance, financial and institutional structures that they have chosen. These might include "rental forms (private, public or social), group forms of ownership (such as trusts, co-operatives, share block schemes and communal property associations) and sectional title ownership (in medium and high density accommodation in apartment blocks or townhouse complexes)" (Royston, 2012).

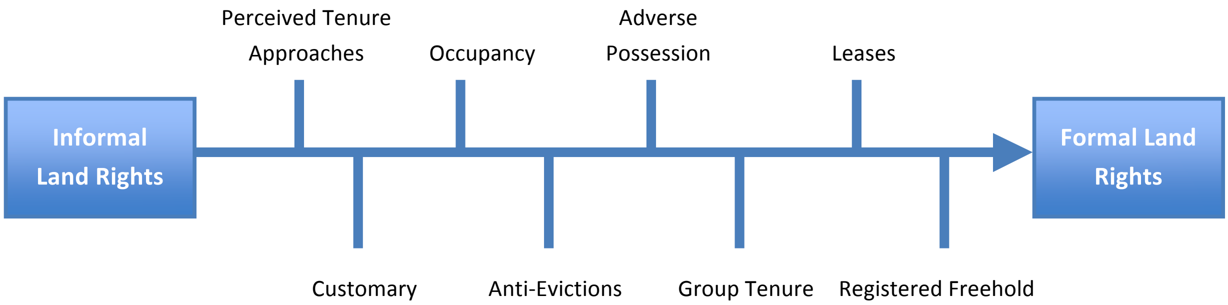

Figure 6.5: Continuum of Land Rights
Source: Lemmen (2008)

With increasingly secure tenure, numerous opportunities suddenly emerge. As the legal standing of residents increases (they may now have an address and documentation to prove it), stigmatisation is reduced and the ability to enter the formal labour market or using land and dwelling as collateral becomes a possibility (Rojas, 2010).

b) *Incorporation of existing infrastructures* – In the absence of formalised service provision, poor communities ingeniously develop their own storm water systems, drainage, urinals, electrical connections, public roads, paved walkways and other public amenities. These represent significant sunk investments and should be incorporated as much as possible into newly introduced infrastructures, something that a flexible community-driven process will inevitably ensure[44]. Furthermore, many slum dwellers would prefer to be legal residents who pay for the services they receive. This is evidenced through wilful formalisation of illegal and informal service connections, such as water, sanitation and electricity connections. This incrementalist approach has the benefit of combining "the ingenuity of the informal with the advantages of formalization" (Bradlow, 2011b:1) [45].

c) *Appropriate Timeframes* – Inherent to the principle of Incrementalism is an appreciation of the value of doing things gradually over time. The concept naturally speaks to layers of interventions

[44] See for example Pervaiz et al. (2008) for a description of the Orangee Pilot Project in Karachi where Community sanitation infrastructure was connected to municipal systems.
[45] Bradlow (2011b) describes the case of Kosovo in Nairobi where, through a participative process, the militia controlled informal water supply was converted into formal connections, which were paid for.

that cumulatively add up to something greater. It is a well-known fact that building pride and acceptance within communities requires self-investments. SDI's experience has been that a 10% contribution to project costs builds ownership and trust within communities to manage upgrading projects themselves (Bradlow, 2010b). Enumeration is a useful tool to derive an understanding of the economic position of residents and the timelines needed for proper savings activities to commence. Upgrading should proceed at a pace that is appropriate and acceptable to slum residents themselves and may vary between settlements. This aspect may not sit easily with governments eager to 'eradicate' their slums and with performance targets at hand, yet is essential to any successful upgrade.

"Personal and local resources are imagination, initiative, commitment and responsibility, skill and muscle power; the capability for using specific and often irregular areas of land or locally available materials and tools; the ability to organise enterprises and local institutions; constructive capacity and the capacity to co-operate" (Turner, 1991:48). These are the resources that can be unlocked if collectivity, flexibility and incrementalism become the foundation of slum upgrading processes.

6.9 Linking Success Principles with Shortcomings

The Principles for successful upgrading derived from the case study above may be seen as a response to the shortcomings of the UISP, which were discussed in depth in Section 2.2.3. A precise analysis of the potential of these principles to overcome the UISP deficiencies falls beyond the scope of this study, and may be the subject of discrete research in itself. However, in order to satisfy the reader of the potential improvements that Collective, Flexible and Incremental Upgrading can entail, a brief foray into this domain has been conducted in Figure 6.6 where these principles have been connected with a list of the UISP shortcomings.

A web of possibilities is apparent in which the current informal settlement approach can be improved. To end this section, one strand of possibility (from Figure 6.6) will be explored, namely the Representation through decentralisation (Collectivity principle) proposition. By following its links to numerous UISP shortcomings, the use of this diagram will be demonstrated: Approaching slum upgrading *collectively through decentralised representation* lessens the *top-down state driven approach* which is *prescriptive and quashes flexibility,* in the interest of including alternatives which may be more important to communities. A participative process enhances community acceptance of upgrades, improves inter and intra-community dialogues and holds the potential to *strengthen social relationships* as opposed to diminishing them.

Through this analysis, the final Research Objective 5 (*Derive a set of principles that should underlie an alternative notion of in situ incremental upgrading with regards to sustainable energy and shelter improvements)* has been addressed.

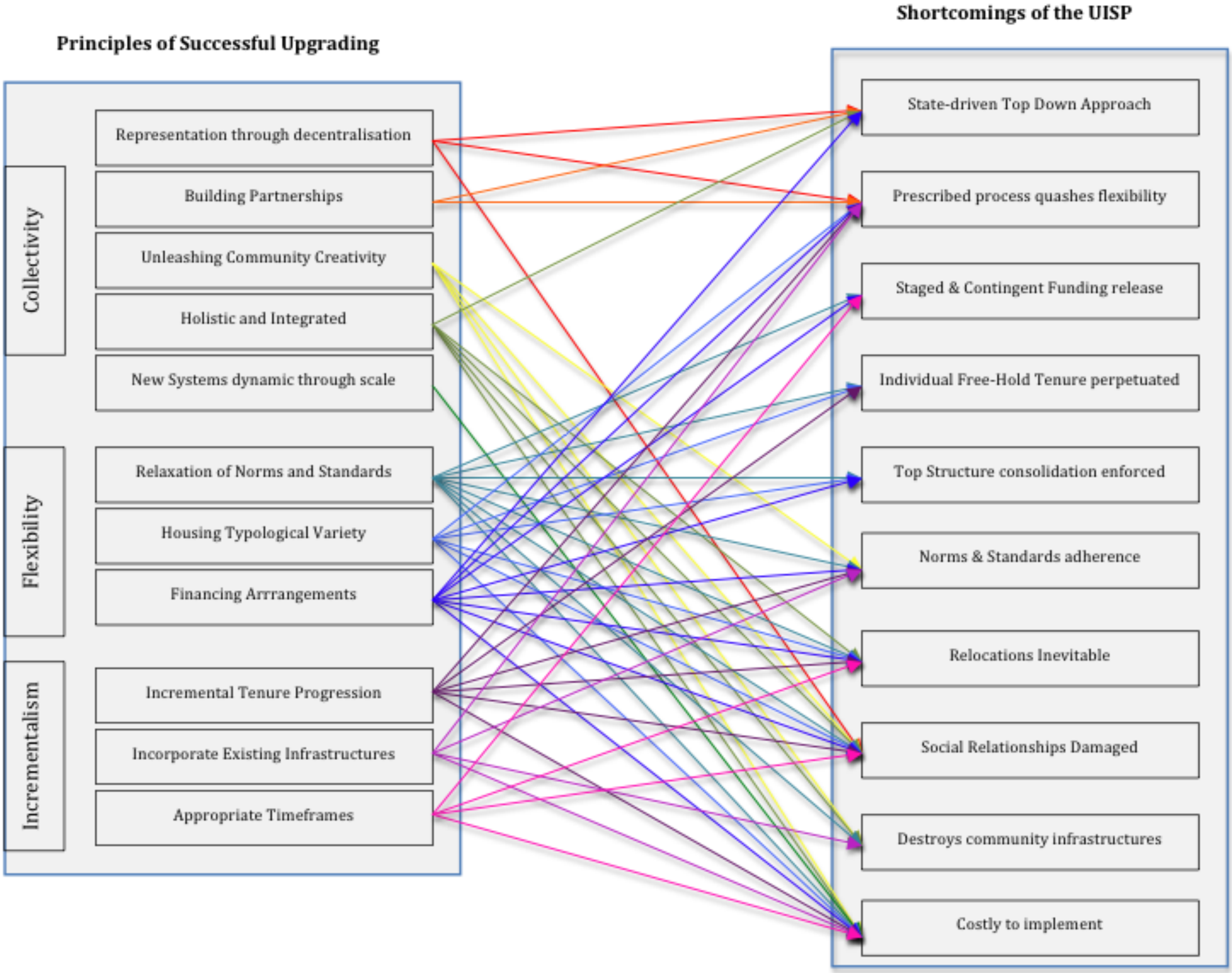

Figure 6.6: Causation Map linking the Principles of Successful Upgrading with the Shortcomings of the UISP

Source: Author (2012)

6.10 Conclusion

The transformation knowledge necessary to action the energy-shelter target knowledge transitions was developed in this chapter through an analysis of the human settlements and energy policy space. The Free Basic Alternative Energy (FBAE) policy is a viable sustainable energy enabler if its financial, administrative and logistical bottlenecks are resolved. The payback period of the DC Multigrid system under FBAE was 3 years 4 months, a figure that could be reduced to 2 years and 2 months if reasonable level of user contributions was added.

The Housing Subsidy Quantum currently has no dedicated mechanism to address incremental top structure improvements of slum dwellers, save for the provision of formalised housing. The Emergency Housing Programme was found to hold the potential to enable energy-poverty alleviating shelter improvements albeit only in emergencies and not at a significant enough scale. A case study approach was used to derive a core set of principles for successful upgrading which could inform a policy iteration that may more adequately address the shelter needs South Africa's informal settlers.

Chapter Seven: Concluding Arguments and Areas for Future Research

7.1 Introduction

In this chapter, the researcher will conclude this study with a narrative account of its salient arguments by drawing on the results of the previous chapters and linking them with the research objectives that were set in Chapter 1. In order to frame the ensuing synthesis, it may be useful to remind the reader of the primary research question and the research objectives of this work.

The primary research question was:

What role can additional sustainable energy and shelter improvements play in alleviating energy poverty during in situ incremental upgrading of informal settlements?

In order to answer this problem statement, the following research objectives were identified:

1. Determine what the current South African policy and practice is in regards to in situ informal settlement upgrading and pro-poor energy improvements (*Systems knowledge*).

2. Investigate whether the current human settlements and energy policies affect energy poverty at the informal household level (*Systems knowledge*).

3. Explore alternative sustainable energy and in situ upgrading shelter improvement responses that may simultaneously be energy poverty alleviators (*Target knowledge*).

4. Identify spaces within the human settlements and energy policies that could support sustainable energy and shelter improvements (*Transformation knowledge*).

5. Derive a set of principles that should underlie an alternative notion of in situ incremental upgrading with regards to sustainable energy and shelter improvements (*Transformation knowledge*).

7.2 Outline of Main Argument

7.2.1 Policy and Practice: Informal Settlement Upgrading and Pro-poor Energy

The first research objective was addressed in the first section of the Literature Review (Chapter 2) where a systems knowledge understanding of the current policy and practise in regards to in situ informal settlement upgrading and pro-poor energy policies was investigated.

South Africa's most recent and significant human settlements policy revision which came in the form of the *Breaking New Ground: A Comprehensive Plan for the Development of Sustainable Human Settlements* (BNG) policy which sought to address many of the shortcoming of the original RDP housing policy and paved the way for the formation of the Upgrading of Informal Settlements Programme (UISP). Underlying BNG and the UISP is a paradigmatic shift in the approach to human settlements development through the incorporation of the principles of situated (*in situ*) and phased (*incremental*) upgrading. Significant programmatic and implementation shortcomings characterise the UISP, which emerge due to a prescribed phased approach that enforces its adherence through contingent funding releases. The UISP in its current form perpetuates the socio-spatial logic of the Apartheid City which involves relocations, economic and social dislocation, demographic and spatial fragmentation and low-density urban sprawl. South Africa's cities remain exclusive domains, inaccessible in formal terms, to the large majority of its poorer residents.

The spatial and economic marginalisation of South Africa's poor urban majority, exacerbated through past and present housing policies, has direct energy poverty entrenching dynamics by dislocating the poor from clean energy markets, employment opportunities and increasing their daily transportation spend. Energy poverty in the context of this work was defined as "the absence of sufficient choice in accessing adequate, affordable, reliable, quality, safe and environmentally benign energy sources to support economic and human development" (UNDP (2000) in TERI, 2008:2). The relationship between energy and poverty is one of mutual causation: Higher levels of poverty are associated with traditional fuels purchase patterns used in inefficient appliances; whilst the provision of clean and reliable energy sources can be a catalyst for human development.

The National Electrification Programme and Free Basic Electricity subsidy, South Africa's primary pro-poor energy policies, have enabled significant cleaner fuel transitions, yet have been ineffective in alleviating energy poverty at the informal household level. The policy implementation logic is the root cause of this, through the insistence on prepayment metering technology, an insufficient free basic electricity quota and the practice of current limiting. Informal households remain in a state of energy deprivation, having to rationalise energy expenditure and continuing their reliance on traditional fuels used in inefficient and polluting appliances.

7.2.2 Energy Poverty

Against the backdrop of the human settlements and pro-poor energy policies the researcher considered the second research objective, which was to determine whether these policies had an effect on the energy poverty of informal settlers.

It was found that the intersection of the human settlements and pro-poor energy policies resulted in an 'All or Nothing' approach to shelter and energy infrastructure provision. The energy poverty alleviating options under the policy status quo are limited – either an informal settler lives in an unelectrified shack or an electrified shack or an electrified house. Given the current housing backlog, resource constraints and high norms and standards, this implies that shelter formalisation will elude most informal settlers for decades to come.

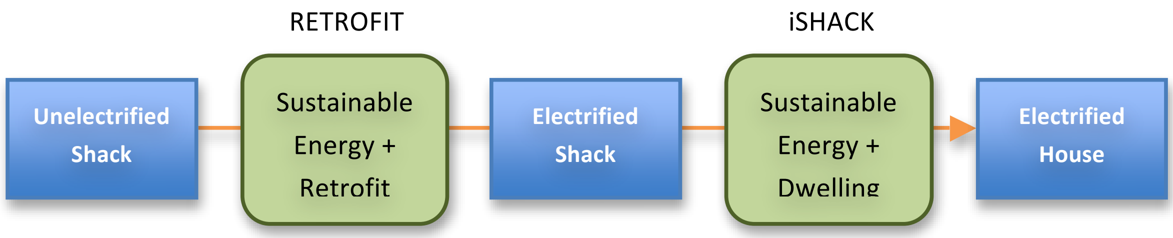

Figure 7.1: Stylised Energy-Shelter Trajectory
Source: Author (2012)

A stylised Energy-Shelter Trajectory (Figure 7.1) composed of the abovementioned discrete energy-shelter steps, enables the identification of spaces where additional energy poverty alleviating measures could be introduced. In the context of this study, these were identified as a sustainable energy & insulation retrofit intervention ('Retrofit') and a sustainable energy & improved dwelling intervention (iShack). These additional Energy-Shelter incremental responses were investigated further in order to determine their precise form and function as well as their potential to reduce household energy poverty.

7.2.3 Alternative Energy-Shelter responses

In Chapter 3, systems knowledge was further populated to inform the target knowledge necessary for additional Energy-Shelter transitions. A brief review of the fuel transitions literature shed light onto the circumstantial drivers that stimulate energy transitions from inferior to clean fuels, as well as the fuel use patterns of poor people. This laid the backdrop against which to conduct a technology review given that the introduction of a sustainable energy component implies a transition in energy carrier or appliance. A DC Multigrid solar system was deemed the most promising sustainable energy technology since it enabled complete traditional fuel substitution due to its ability to deliver all energy services (save for space heating) at an equivalent service level to grid electricity. Furthermore, the technology has no 'in-use' emissions, insulates users from fuel price hikes due to the free solar fuel, can be incrementally scaled up over time and in accordance to user budgets and preferences, and is fully integrateable with the AC grid. On the shelter front, an investigation into prior work in the field of sustainable informal shelter construction (ecological design, fire retardant materials, blocking out) was complemented with information from informal settlers themselves as it related to the decision making processes that informed their shelter design and construction.

7.2.4 Designing and Testing the Retrofit and iShack

Moving onto the third research objective involved an exploration of alternative sustainable energy and in situ upgrading shelter improvement responses that could simultaneously be energy poverty alleviators. The systems knowledge inputs were fed into an iterative, transdisciplinary design process that gave rise to target knowledge of the precise form of the Retrofit and iShack responses (Chapter 4). In order to test their efficacy at being energy poverty alleviators, an existing shack was retrofitted (Retrofit) and a new dwelling was constructed (iShack), both in line with ecological design and insulation material interventions and the latter including a DC Multigrid system.

Indoor and Outdoor Temperature recordings of the Retrofit and iShack were taken over a 7 week period with an additional non-intervened Control shack as a benchmark for comparison. A statistical analysis of these readings (Chapter 5) revealed superior thermal performance results for both the iShack and Retrofit shack with reductions in Indoor Temperature fluctuations, an increased buffering effect between Indoor and Outdoor Temperature Differences, and a longer time lag for Indoor Temperatures to match Outdoor Temperature stimuli. Furthermore, net additions in Thermal Comfort were also realised in the order of an additional 3h34m and 4h45m for the Retrofit and iShack respectively.

The challenge of linking Thermal Comfort performance with energy poverty revolves around the incommensurability of benefits that are unlocked through these interventions, which cannot be reduced to monetary or emissions figures. Save for reduction in traditional energy use for lighting (iShack) and space heating during cool periods (Retrofit & iShack), the energy poverty alleviating effects were most discernable through the feedback of users. The Retrofit and iShack households revealed significant socio-economic benefits which, due to the mutual causation between clean energy and economic standing, can be deemed to have a diminishing effect on energy poverty.

7.2.5 Embedding Energy-Shelter Responses within the current policy paradigm

Generating the transformation knowledge necessary to actuate energy poverty alleviating sustainable energy interventions satisfied research Objective 4, through a re-examination of the human settlements and energy policy, in order to find the policy space where these transitions could be supported (Chapter 6).

At a current monthly household allocation of R81.53, the Free Basic Alternative Energy subsidy was found to hold significant potential in funding the access cost of the DC Multigrid system, especially if coupled with supplementary sources of income. In order to be effective however, current financial, administrative and logistical policy bottlenecks that are hampering its rollout need to be resolved.

The human settlement policy currently has no dedicated subsidy mechanism to address the top structure of slum dwellers. Only through the Emergency Housing Programme (EHP) can sustainable and incremental shelter responses be explored and depend on the interpretation of the definition of 'emergency' as well as the foresight of programme implementers. However, given the sheer scale of informality in South Africa, the limited funding available under the programme, the prioritisation of the most needy informal settlers and the predominant focus on formalised human settlements development, the EHP is not a sufficient policy response to facilitate additional energy-shelter transitions prior to grid electrical infrastructure and formalised housing provision. A dedicated policy instrument that effectively and equitably expedites measures to improve the shelter conditions of slum dwellers, whilst still living informally, is required.

7.2.6 Developing core principles for alternative in situ incremental upgrading

Following the understanding that the human settlements policy currently does not have sufficient scope to action developmental responses at the level of the informal shack, the final part of this study was to determine the core principles that could inform a policy iteration in favour of a more flexible, responsive and inclusive policy-sanctioned approach to addressing informality in South Africa (Chapter 6). This matched the final research objective which sought to derive a set of principles that should underlie an alternative notion of in situ incremental upgrading with regards to sustainable energy and shelter improvements.

A case study of the Thai version of the UISP, the Baan Mankong Programme, and the Bang Bua canal-side settlement upgrade provided lessons which informed the distillation of three core principles for successful upgrading, namely Collectivity, Flexibility and Incrementalism. A causation map identified the spaces where these principles could address the shortcomings of the UISP principles as they relate to financing, governance, infrastructure, housing typologies, welfare systems and tenure arrangements.

7.3 Recommendations for Future Research

7.3.1 Review of UISP to enable alternative energy-shelter responses

In Chapter 6, an initial attempt was made at distilling a core set of principles that enabled Thai slum communities to action inclusive, holistic and incremental upgrading of their settlements. This exercise was borne out of a need to reconceptualise the current Upgrading of Informal Settlements Programme, since its shortcomings fail to deliver on its constitutional mandate of adequate shelter timeously, at scale and with beneficial outcomes for communities.

Future research in this domain may seek to develop the principles for successful upgrading (Collectivity, Flexibility and Incrementalism) further whilst making provision for additional incremental shelter responses over and above those advocated in this work.

7.3.2 Development Informal Shelter Design Criteria

In this study the researcher was faced with the challenge of selecting design criteria for dwellings for which no objective benchmark is currently available. This represents a failure on behalf of academic, NGOs and government in light of the realisation that informal settlements are not a fleeting phenomenon, and is a quiet attestation to the entrenched fixation on formalisation.

Shelter design criteria are a necessary means by which to determine the *adequacy* of all shelter, including informal shelter, a term which, in the context of this thesis, and given its heightened importance due to the universal constitutional right to 'adequate shelter', is something which researchers may want to clarify and develop in future work. This may involve devising a rapid informal shelter assessment tool by which appropriate energy-shelter responses may be equitably expedited.

7.3.3 Developed further Energy-Shelter responses

The iShack and Retrofit shacks were initial forays into finding alternative developmental responses to expedite slum upgrading in a more flexible, sustainable and affordable fashion and were approached through the lens of energy-poverty alleviation. Opportunities exist by linking energy-shelter responses with livelihoods, social amenities and the stimulation of micro enterprises and social entrepreneurship.

Future research might also investigate further iShack typologies in regards to alternative construction and insulation materials usage, designs applicable to higher densities (including double storey shacks), building in suboptimal condition (e.g. where north facing orientation is not available) and where certain dwelling components may be shared (e.g. a cob wall on a back-to-back shack). These may constitute additional increments along the stylised Energy-Shelter trajectory postulated in this work.

The success of building with recycled materials at a significant scale is reliant upon a supply chain of recycled materials. Future researchers may furthermore look at linking industry waste streams and recyclers with reprocessing facilities which, in turn, can supply informal settlers with quality recycled insulation and construction materials.

7.3.4 Pilot DC Multigrid technology at scale

The discussion in Section 3.4.1 highlighted the fact that the DC Multigrid energy intervention requires the availability of maintenance and repair infrastructure and user training in order to ensure system longevity and correct functioning (something that is necessary for all Solar PV systems). Furthermore, in Section 6.2, it was calculated that a significantly reduced payback period emerged through reasonable user contributions to the systems cost.

Future researchers may attempt to combine these threads by designing an institutional model, which can support repairs and maintenance activities and manages the collection of payments. The model would need to clarify aspects such as a) asset ownership – individual versus communal, b) repairs and maintenance – mandatory or voluntary, and their frequency, c) repayment process – outright sale, rent-to-own, full rental, and d) financing options – micro-finance, state subsidy, individual contribution and/or combinations thereof.

Testing the institutional model through a pilot project would shed light onto the dynamics that have an effect on its efficacy, and should include a phased upscale from individual to neighbourhood to district level, since the underlying institutional model must be flexible enough to adapt. (This research is already underway – see Wessels, forthcoming).

References

Adam, F. 2010. *Free Basic Electricity: A better life for all*. Johannesburg: Earthlife.

Adeoti, O., Idowu, D. O. O., Falegan, T. 2001. Could fuelwood use contribute to household poverty in Nigeria? *Biomass and Bioenergy*, 21(3):205-210.

African National Congress (ANC), 1994. *The Reconstruction and Development Plan.* Johannesburg: Umanyano.

African National Congress (ANC), 2000. ANC Local Government Elections 2000 Manifesto [Online]. Available: http://www.anc.org.za/docs/manifesto/2000/ANC%20LOCAL%20GOVERNMENT%20ELECTI...pdf [27 June 2011].

Annecke, W. & Endelli, M. 2006. Gender and Prepayment Electricity in Merlo, Argentina. *Energia News*, 9(1):18-20.

Annecke, W. 2008. Still in the shadows: Women and gender relations in the electricity sector in South Africa. *In* McDonald, D. (ed.), *Electric Capitalism: Recolonising Africa on the power grid.* Cape Town: HSRC Press.

Annecke, W., Mohlakoana, N., Dobbins, A. 2008. *From Electricity to LPG and back again: Power Cuts, LPG Supply and the Poor in Khayelitsha 2006/2007*. Johannesburg: South African National Energy Research Institute.

Asian Coalition for Housing Rights (ACHR), 2009. A conversation about upgrading at Bang Bua. [Online]. Available: http://pubs.iied.org/G02376.html. [Accessed: 8 May 2012].

Baccini, P. & Oswald, F. 2007. Designing the Urban: Linking Physiology with Morphology. *In* Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., Zemp, E. (eds.), *Handbook of Transdisciplinary Research*. Bern: Springer.

Barnes, D., Khandker, S., Samad, H. 2011. Energy poverty in rural Bangladesh. *Energy Policy*, 39(3): 893-904.

Batliwala, S. & Reddy, A. 2003. Energy for women and women for energy (engendering energy and empowering women). *Energy for Sustainable Development,* 7(3):33-43.

Bekker, B., Eberhard, A., Gaunt, T., Marquard, A. 2008. South Africa's rapid electrification programme: Policy, institutional, planning, financing and technical innovations. *Energy Policy*, 36(8):3125-3127.

Bhide, A., Monroy, R. 2011. Energy poverty: A special focus on energy poverty in India and renewable energy technologies. *Renewable and Sustainable Energy Reviews*,15(2):1057–1066.

Bhutto, A. & Karim, S. 2007. Energy-poverty alleviation in Pakistan through use of indigenous energy resources. *Energy for Sustainable Development*, 11(1):58-67.

Bolnick, A. 2010. *Informal Settlement Upgrading: Towards an Incremental People Centered Approach*. [Online] Community Organisation Resource Center. Available at: http://www.sasdialliance.org.za/static/upload/docs/Informal_Settlement_Upgrading.pdf [Accessed: 28 May 2012].

Boonyabancha, S. 2005 Baan Mankong: going to scale with "slum" and squatter upgrading in Thailand. *Environment & Urbanization,* 17(1):21-46.

Borchers, M., Brown, M., Mahomed, L. 2008. Energy Planning in South African cities. *In* Droege, P. (ed.), *Urban Energy Transition: From Fossil Fuels to Renewable Power*. Amsterdam: Elsevier.

Bradlow, B. 2010a. A brief introduction to partnership-based upgrading. *SDINet.org* blog, [blog] 30 November. Available at: http://www.sdinet.org/blog/2010/11/30/a-brief-introduction-to-partne/ [Accessed: 16 April 2012].

Bradlow, B. 2010b. What is incrementalism? *SDINet.org* blog, [blog] 21 May. Available at: http://www.sdinet.org/blog/2010/05/21/what-is-incrementalism/ [Accessed: 16 April 2012].

Bradlow, B. 2011a. Between the "informal" and the "formal": Slum upgrading in South Africa. *SDINet.org* blog, [blog] 28 June. Available at: http://www.sdinet.org/blog/2011/06/28/between-informal-and-formal-slum-upgrading-south-a/ [Accessed: 25 May 2012].

Bradlow, B. 2011b. What is incrementalism, part 2: Community-managed utilities in an informal settlement in Nairobi. *SDINet.org* blog, [blog] 23 May. Available at: http://www.sdinet.org/blog/2011/05/23/what-is-incrementalism-part-2-/ [Accessed: 16 April 2012].

Bradlow, B., Bolnick, J., Shearing, C. 2011. Housing, institutions, money: the failures and promise of human settlements policy and practice in South Africa. *Environment and Urbanisation*, 23(1):267-275.

Bredenoord, J. & Van Lindert, P. 2010. Pro-poor housing policies: Rethinking the potential of assisted self-help housing. *Habitat International*, 34(3): 278-287.

Brewer, G. 1999. The Challenges of Interdisciplinarity. *Policy Sciences* (32): 327-337.

Burger, J., Swilling, M., Lengkeek, J. 2010. A Sustainable Housing Calculator: Demonstrating the long term benefits of sustainable building interventions. *Human Settlements Review* 1(1): 101-117.

Callon, M. 1999. The Role of Lay People in the Production and Dissemination of Scientific Knowledge. *Science, Technology & Society*, 4(1): 81-94.

Carolissen, D. 2011. Director of Informal Settlements, Stellenbosch Municipality. Personal Interview on 16 March 2011, Stellenbosch.

Charlton, S. & Kihato, C. 2006. Reaching the poor? An analysis of the influences on the evolution of South Africa's housing programme. *In* Pillay, U., Tomlinson, R., Du Toit, J. (eds.), *Democracy and Delivery: Urban Policy in South Africa*. Cape Town: HSRC Press.

Cities Alliance, n.d. *What is Slum Upgrading*. [Online] Cities Alliance. Available at: http://www.citiesalliance.org/slum-upgrading%20 [Accessed: 25 May 2012].

City of Cape Town (CoCT), 2010. Five Year Integrated Housing Plan 2010/11 – 2014/15. [Online] City of Cape Town. Available at: http://www.capetown.gov.za/en/Housing/Documents/5_Year_Integrated_Housing_Plan_2010.pdf [Accessed: 07 June 2012].

Clancy, J., Maduka, O., Lumampao, F. 2008. *In* Droege, P. (ed.), *Urban Energy Transition: From Fossil Fuels to Renewable Power*. Amsterdam: Elsevier.

Cohen, L. 2009. eMatinini - *Place of Tin. The Provision of Public Housing in South Africa: The Impact and Effect of Transit Camps on Residents and its Place in the Provision of Housing* [Online]. Available: http://abahlali.org/node/6155 [Accessed: 5 July 2011].

Cowan, B., Mohlakoana, N. 2005. Barriers to modern energy services in low-income urban communities: Khayelitsha energy survey, 2004. Cape Town: University of Cape Town.

Creamer, T. 2011. Tariffs underpin Eskom's profit surge, as demand growth remains modest. *Engineering News* [Online] 27 June. Available: http://www.engineeringnews.co.za/article/tariffs-underpin-eskoms-profit-surge-as-demand-growth-remains-modest-2011-06-27. [Accessed: 5 July 2011]

Cronin, K. 2008. Transdisciplinary Research (TDR) and Sustainability. Christchurch: Environmental Science and Research.

Cuff, S. 2007. *PEP Ikhaya Lami.* Cape Town: People's Environmental Planning.

Cuff, S. 2011. Chief Executive Officer of People's Environmental Planning. Personal Interview on 03 June 2011. Cape Town.

Dasgupta, S., Deichmann, U., Meisner, C., Wheeler, D. 2005. Where is the Poverty– Environment Nexus? Evidence from Cambodia, Lao PDR, and Vietnam. *World Development*, 33(4):617-638.

Del Mistro, R. & Hensher, D. 2009. Upgrading Informal Settlements in South Africa: Policy, Rhetoric and what Residents really Value. *Housing Studies*, 24(3): 333-354.

Department of Energy (DoE), 2012. *Petrol Price Archive* [Online]. Available: http://www.energy.gov.za/files/esources/petroleum/petroleum_arch.html. [Accessed: 5 July 2011].

Department of Housing (DoH), 2004. *Breaking New Ground: A Comprehensive Plan for the Development of Sustainable Human Settlements*. Pretoria: Department of Housing.

Department of Human Settlements (DHS), 2009. *Emergency Housing Programme*, Part 3, Volume 4 of the National Housing Code. Pretoria: Department of Humans Settlements.

Department of Human Settlements (DHS), 2009. *The National Housing Code*. Pretoria: Department of Human Settlements.

Department of Human Settlements (DHS), 2010. The Use of Alternative Technologies in Low Cost Housing Construction: Why the Slow Pace of Delivery? *Human Settlements Review,* 1(1): 266-270.

Department of Minerals and Energy (DME), 2001. *National Electrification Programme (NEP) 1994 – 1999 Summary Evaluation Report.* Pretoria: DME.

Department of Minerals and Energy (DME), 2003a. *Electricity Basic Services Support Tariff (Free Basic Electricity) Policy*. Pretoria: DME.

Department of Minerals and Energy (DME), 2003b. *Guidelines for the Introduction of Free Basic Electricity Service*. Pretoria: DME.

Department of Minerals and Energy (DME), 2007. *Free Basic Alternative Energy Policy*. Pretoria: DME.

Development Action Group (DAG), 2007. *Upgrading Informal Settlements: South African Policy and Praxis.* Cape Town: DAG.

Djongyang, N., Thinda, R., Njomo, D. 2010. Thermal comfort: a review paper*. Renewable and Sustainable Energy Reviews*, 14(9): 2626-2640.

Donnelly D. 2012. Eskom get cracking on to-do list. *Mail & Guardian* [online] 16 March. Available: http://mg.co.za/article/2012-03-16-eskom-gets-cracking-on-todo-list/ [Accessed: 08 August 2012].

Durrheim, K. & Painter, D. 2006. Collecting Qualitative Data: Sampling and measuring. *In* Terre Blanche, M., Durrheim, K., Painter, D. (eds.), *Research in Practice*. Cape Town: UCT Press.

Eco Design Architects, n.d. Moon Phase Harvesting of Timber – Correction of Dates [Online]. Available: http://www.ecodesignarchitects.co.za/eco-design-news/ecodesign-news-current-events/145-moon-phase-harvesting-of-timber.html [Accessed: 3 May 2012].

Eisenhardt, M. Building theories from case study research. *Academy of Management Review,* 14(4):532-550.

Elias, R. & Victor, D. 2005. *Energy Transitions in Developing Countries: a Review of Concepts and Literature.* Stanford: Program on Energy and Sustainable Development.

Energy Research Center (ERC), 2008. The supply of clean energy services to the urban and peri-urban poor. Cape Town: University of Cape Town.

Energy Services Management Assistance Program (ESMAP), 2007. *Sub-Saharan Africa: Introducing Low-cost Methods in Electricity Distribution Networks*. Washington, DC: The World Bank.

Environmental Evaluation Unit (EEU), 2004. *DIY Home Insulation Kit Project Final Report – July 2004*. Cape Town: University of Cape Town.

Fieuw, W. 2011. *Informal Settlement Upgrading in Cape Town's Hangberg: Local Government, Urban Governance and the 'Right to the City'.* MPhil Dissertation. Stellenbosch University.

Flyvbjerg, B. 2006. Five Misunderstandings About Case-Study Research. *Qualitative Inquiry* 12(2): 219-245.

Foster, V. 2000. Measuring the impact of energy reform – practical options. In The World Bank (eds.), *Energy and Development Report 2000*, p.34-42.

Gallopin, G. 2003*. A Systems Approach to Sustainability and Sustainable Development*: Project NET/00/063. Santiago: Economic Commission for Latin America.

Gaunt, C. 2005. Meeting electrification's social objectives in South Africa, and implications for developing countries. *Energy Policy,* 33(10):1309-1317.

Gaunt, C. 2008. Electricity distribution industry restructuring in South Africa: A case study. *Energy Policy*, 36(9):3448-3459.

Goebel, A. 2007. Sustainable urban development? Low-cost housing challenges in South Africa. *Habitat International*, 31(3-4):291-302.

Goldman, M. 2010. *Kuyasa CDM project: renewable energy efficiency for the poor*. [Online] Growing Inclusive Markets. Available at: http://cases.growinginclusivemarkets.org/documents/112 [Accessed: 07 June 2012].

Govender, T., Barnes, J., Pieper, C. 2011. Housing conditions, sanitation status and associated health risks in selected subsidized low-cost housing settlements in Cape Town, South Africa. *Habitat International*, 35(2): 335-342.

Government of Australia, n.d. *Design for Lifestyle and the Future: Your Home.* Australia: Government of Australia [Online]. Available from www.yourhome.gov.au/technical/index.html [03 May 2012].

Guy, M., Annegarn, H., Eland, T. 2008. Witsand IEEECO™ Village Assessment of Thermal Performance of IEEECO™ Units [Online]. Available: http://active.cput.ac.za/energy/web/DUE/DOCS/287/Paper%20%20Mothusi%20Guy%20D.pdf. [Accessed: 03 May 2012].

Heun, M., Brent, A. Fluri, T., Meyer, A., Swilling, M., Van Niekerk, J. 2010. Learnable Lessons on Sustainability from the Provision of Electricity in South Africa. *Proceedings of the ASME 2010 4th International Conference on Energy Sustainability*. Phoenix, USA, 17-22 May 2010 Conference Paper. New York: American Society of Mechanical Engineers.

Hodgson, J. 2011. Chief Executive Officer, Specialized Solar Systems (Pty) Ltd. Personal Interview on 9 July 2011, George.

Holm, D. & Engelbrecht, F. 2005. Practical choice of thermal comfort scale and range in naturally ventilated buildings in South Africa. *Journal of the South African Institution of Civil Engineering*, 47(2):9-14.

Housing Development Agency, 2012. *Implementation of Emergency Housing*. Johannesburg: The Housing Development Agency.

Howells, M., Jonsson, S., Kack, E., Lloyd, P., Bennett, K., Leiman, T., Conradie, B. 2010. Calabashes for kilowatt-hours: Rural energy and market failure. *Energy Policy*, 38(6):2729-2739.

Huchzermeyer, M. 2001. Housing for the poor? Negotiated housing policy in South Africa. *Habitat International,* 25(3): 303-331.

Huchzermeyer, M. 2006. The new instrument for upgrading informal settlements in South Africa: Contributions and constraints. *In* Huchzermeyer, M. & Karam, A. (eds.), *Informal Settlements: A Perpetual Challenge?* Cape Town: Juta.

Huchzermeyer, M. 2009. The struggle for *in situ* upgrading of informal settlements: a reflection on cases in Gauteng. *Development Southern Africa,* 26(1):59-73.

Huchzermeyer, M. 2010. Pounding at the Tip of the Iceberg: The Dominant Politics of Informal Settlement Eradication in South Africa. *Politikon*, 37(1): 129-148.

Iliev, I. 2005. *Resource-based Technology Innovation in South Africa: Pre-paid Metering Technology – Systemic Innovation in the South African Energy Sector*. Pretoria: Human Sciences Research Council.

International Cooperative Association, n.d. *What is a co-operative?.* [Online] Available at: http://www.ica.coop/coop/index.html [Accessed: 25 May 2012].

International Energy Agency (IEA), 2010*. Comparative Study on Rural Electrification Policies in Emerging Economies.* Paris: International Energy Agency.

Jaglin, S. 2008. Differentiating networked services in Cape Town: Echoes of splintering urbanism? *Geoforum*, 39(6):1897-1906.

Jaglin, S. 2009. Between electricity crisis and "green hub" marketing: changes in urban energy policies and governance in Cape Town. *Proceedings of the Cities and energy transitions: past, present, future International roundtable conference,* Autumn, 1-4 June 2009. Latts, France: ENPC.

Karekezi, S., Kimani, J., Onguru, O., 2008. Energy access among the urban poor in Kenya. *Energy for Sustainable Development*, 12(4): 38-48.

Kaygusuz, K. 2011. Energy services and energy poverty for sustainable rural development. *Renewable and Sustainable Energy Reviews*, 15:(2)*:* 936-947.

Keller, A. 2012. *Research Diary: Personal interviews and reflections*. Stellenbosch.

Kidd, M. 2012. Updated Data, email to A. Keller [Online]. 24 April 2012. Available email: mkidd@sun.ac.za.

Klug, N. & Vawda, S. 2009. Upgrading of Informal Settlements: An Assessment with Reference to the Application of 'Breaking New Ground' in Cape Town and Johannesburg. *Town and Regional Planning*, 54: 37-49.

Landman, K. & Napier, M. 2010. Waiting for a house or building your own? Reconsidering state provision, aided and unaided self-help in South Africa. *Habitat International*, 34(3): 299-305.

Lawrence, R. 2006. Housing and Health: Beyond Disciplinary Confinement. *Journal of Urban Health,* 83(3): 540-549.

Lemmen, C. 2010. *The Social Tenure Domain Model*. Copenhagen: International Federation of Surveyors.

Liddell, C. & Morris, C. 2010. Fuel poverty and human health: A review of recent evidence. *Energy Policy,* 38(6): 2987-2997.

Lindegger, G. 2006. Research methods in clinical research. In Terre Blanche, M., Durrheim, K. & Painter, D. *Research in Practice*. Cape Town: UCT Press. P455-476.

Loftus, W. 2011. *Sustainable Energies: Thembalethu DC Micro Grid project, George, South Africa*. MEng. Nelson Mandela Metropolitan University

Louw, K., Conradie, B., Howells, M., Dehenak, M. 2008. Determinants of electricity demand for newly electrified low-income African households. *Energy Policy*, 36(8):2812-2818.

Maboda, S. 2011. FBAE Implementation Query, email to A. Keller [Online] 2 June. Available email: sivuyile@sustainable.org.za

Madikizela, B. 2012. Western Cape Department of Human Settlements budget speech 2012 by Mr Bonginkosi Madikizela, MEC of Human Settlements. [Online] South African Government Information. Available: http://www.info.gov.za/speech/DynamicAction?pageid=461&sid=26386&tid=63146. [Accessed: 13 August 2012].

Majale, M. 2008. Employment creation through participatory urban planning and slum upgrading: The case of Kitale, Kenya. *Habitat International*, 32(2): 270-282.

Masera, O., Saatkamp, B., Kammen, D. 2000. From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to Energy Ladder Model. *World Development*, 28(12):2083-2103.

Max-Neef, M. 2005. Foundations of transdisciplinarity. *Ecological Economics*, 53(1):5-16.

Mehlwana, A. 1997. The anthropology of fuels: situational analysis and energy use in urban low-income townships of South Africa. *Energy for Sustainable Development*, 3(5): 5-15.

Misselhorn, M. 2008. *Position Paper on Informal Settlement Upgrading*. Tshwane: Urban LandMark.

Misselhorn, M. 2010. *A New Response to Informal Settlements*. [Online] Landfirst. Available: http://www.landfirst.org.za/index.php?option=com_content&view=article&id=68:a-new-response-to-informal-settlements-&catid=19:articles&Itemid=63 [Accessed: 25 April 2012].

Misselhorn, M. 2010. Chief Executive Officer, Project Preparation Trust. Personal Interview on 18 July 2011, Durban.

Mouton, J. 2008. *How to succeed in your Master's & Doctoral Studies*. Pretoria: Van Schaik.

National Energy Regulator of South Africa (NERSA), 2010. *Annual Report 2009/2010*. Pretoria: NERSA.

National Upgrading Support Programme (NUSP), 2010. *Progress Report National Upgrading Forum 22 September 2010.* Pretoria: Department of Human Settlements.

Nicol, J. & Humphreys, M. 2002. Adaptive thermal comfort and sustainable thermal standards for buildings. *Energy and Buildings*, 34(6): 563-572.

Nissing, C. & Von Blottnitz, H. 2010. Renewable energy for sustainable urban development: Redefining the concept of energisation. *Energy Policy*, 38(5): 2179-2187.

Obeng, G. & Evers, H. 2009. *Solar PV rural electrification and energy-poverty: A review and conceptual framework with reference to Ghana.* Bonn: Center for Development Research.

Openshaw, K. 2010. Biomass energy: Employment generation and its contribution to poverty alleviation. *Biomass and Bioenergy*, 34(3):365-378.

Oxford Dictionaries, n.d. *Incrementalism*. [Online] Oxford Dictionaries. Available at: http://oxforddictionaries.com/definition/incrementalism [Accessed: 08 June 2012].

Pachauri, S., Mueller, A., Kemmler, A., Spreng, D. 2004. On Measuring Energy Poverty in Indian Households. *World Development*, 32(12):2083-2104.

Patel, K. 2009. Land tenure and vulnerability: the social consequences of *in situ* upgrade of informal settlements, a South African case study. *Proceedings of the Universitas 21 International Graduate Research Conference: Sustainable Cities for the Future*, Melbourne & Brisbane, 29 November – 5 December 2009. Birmingham: University of Birmingham.

Paulsen, R. 2010. Surveillance of poison ingestion cases at Prince Mshiyeni Memorial Hospital, Durban, South Africa. *Proceedings of the Safety 2010 Conference*, London. Claremont: The Paraffin Safety Association of Southern Africa.

Pears, A. 2007. Imagining Australia’s energy services futures. *Futures*, 39(2-3): 253-271.

Peck, M., Kruger, G., Van der Merwe, A., Godakumbura, W., Ahuja, R. 2008. Burns and fires from non-electric domestic appliances in low and middle income countries Part I. The scope of the problem. *Burns*, 34(3):303-311.

People’s Environmental Planning (PEP), n.d. *About* [Online]. Available: http://pep.org.za/index.php/who-we-are/about-pep [Accessed: 23 April 2011].

Pereira, M., Sena, J., Freitas, M., Da Silva, N. 2011. Evaluation of the impact of electricity: A comparative analysis of South Africa, China, India and Brazil. *Renewable and Sustainable Energy Reviews*, 15(3): 1427–1441.

Pervaiz, A., Rahman, P., Hasan, A. 2008. *Lessons from Karachi: the role of demonstration, documentation, mapping and relationship building in advocacy for improved urban sanitation and water services*. London: International Institute for Environment and Development.

Pithouse, R. 2009. A Progressive Policy without Progressive Politics: Lessons from the failure to implement 'Breaking New Ground'. *Town and Regional Planning*, 54: 1-14.

Pohl, C. & Hadorn Hirsch, G. 2007. *Principles for Designing Transdisciplinary Research.* Oekom Verlag: München.

Practical Action, 2010. *Poor people's energy outlook 2010*. Warwickshire: The Schumacher Centre for Technology and Development.

Prasad, G. & Visage, E. 2006. *Impact of Energy Reforms on the poor in South Africa*. University of Cape Town: Energy Research Center.

Price, C. W. 2000. Better energy services, better energy sectors – and links with the poor. In The World Bank (eds.), *Energy and Development Report 2000*, p.26-32.

Rahman, M. 2011. Sustainable Squatter Housing in the Developing World: Changing Conceptialization. *International Journal of Architectural Research*, 5(1):143-159.

Rehman, I., Kar, A., Raven, R., Singh, D., Tiwari, J., Jha, R., Sinha, P., Mirza, A. 2010. Rural energy transitions in developing countries: a case of the Uttam Urja initiative in India. *Environmental Science & Policy*, 13(4): 303-311.

Republic of South Africa, 1994. *White Paper on Reconstruction and Development*. Cape Town: Government Printers.

Republic of South Africa, 1996. *Constitution of the Republic of South Africa*. Cape Town: Government Printers.

Roaf, S., Fuentes, M., Thomas S. 2003. *Ecohouse 2: A design guide*. Oxford: Architectural Press.

Rojas, E. 2010. *Building Cities: Neighbourhood Upgrading and Urban Quality of Life.* New York: Cities Alliance. Available at: http://www.citiesalliance.org/sites/citiesalliance.org/files/BuildingCities.pdf [Accessed: 15 April 2012].

Rossini, F. & Porter, A. 1979. Frameworks for integrating disciplinary research. *Research Policy*, 8(1):70–79.

Royston, L. 2012. *Incrementally securing official access to property in informal settlements.* [Online] Afesis-corplan. Available at: http://www.afesis.org.za/Sustainable-Settlements-Articles/incrementally-securing-official-access-to-property-in-informal-settlements [Accessed: 25 May 2012].

Ruddin, L. 2006. You Can Generalize Stupid! Social Scientists, Bent Flyvbjerg, and Case Study Methodology. *Qualitative Inquiry*, 12(4): 797-812.

Ruiters, G. 2007. Contradictions in municipal services in contemporary South Africa: Disciplinary commodification and self-disconnections. *Critical Social Policy*, 27(4):487-508.

Ruiters, G. 2008. Free basic electricity in South Africa: A strategy for helping or containing the poor?. *In* McDonald, D. (ed.), *Electric Capitalism: Recolonising Africa on the power grid.* Cape Town: HSRC Press.

Rust, K. 2007. *Housing Finance in Africa: The state of practice and issues to consider.* [Online] FinMark Trust. Available: http://www.housingfinanceafrica.org/wp-content/uploads/2007/09/HFHI_HFAfrica.pdf. [Accessed: 26 June 2012].

Saghir, J. 2004. Energy and Poverty: Myths, Links and Policy Issues. *Proceedings of the 9th International Energy Forum 2004*, Amsterdam, 22-24 May 2004. Washington, DC: The World Bank.

Sanya, T. 2010. Innovation and Alternative Building Technology within a Sustainable Development Paradigm. *Human Settlements Review*, 1(1): 86-100.

Savings and Credit and Co-operative League (SACCO), n.d. *What is a SACCO?* [Online] Savings and Credit and Co-operative League. Available: http://www.saccol.org.za/what_is_sacco.php. [Accessed: 25 June 2012].

Schuller, T. 2000. *Thinking about Social Capital*. Working Papers of the Global Colloquium on Supporting Lifelong Learning [online], Milton Keynes, UK: Open University. Available from http://www.open.ac.uk/lifelong-learning [Accessed: 13 June 2011].

Siddiqui, A., Lee, K., Gold, E., Bhutta, Z. 2005. Eye and respiratory symptoms among women exposed to wood smoke emitted from indoor cooking: a study from southern Pakistan. *Energy for Sustainable Development*, 9(3):58-66.

Silva, D. & Nakata, T. 2009. Multi-objective assessment of rural electrification in remote areas with poverty considerations. *Energy Policy*, 37(8): 3096-3108.

Slum Dwellers International (SDI), 2007. *Savings and Credit & Community Funds Seminar.* [Online] Slum Dwellers International. Available at: http://www.sdinet.org/media/upload/countries/documents/government_house_report_tom_kerr.pdf [Accessed: 25 May 2012].

Slum Dwellers International (SDI), 2011. *"Upgrading Lives, Building A Nation". A Pledge for renewal for the South African SDI Alliance* [Online]. Available: http://www.sasdialliance.org.za/static/upload/docs/Upgrading_Lives_Building_The_Nation.pdf [Accessed: 14 February 2011].

South African Cities Network (SACN), 2011. *State of the Cities Report 2011*. South Africa: South African Cities Network.

South African National Energy Research Institute (SANERI), 2008. *Improving Energy Welfare in Unelectrified Urban Informal Households*. Johannesburg: SANERI.

South African Press Association (SAPA), 2010. Nersa exceeding mandate on municipal power tariffs – Shiceka. *Engineering News* [Online] 25 March 2010. Available: http://www.engineeringnews.co.za/article/nersa-exceeding-mandate-on-municipal-power-tariffs-shiceka-2010-03-25 [Accessed: 10 January 2012].

Sovacool, B. 2011. Conceptualizing urban household energy use: Climbing the ''Energy Services Ladder''. *Energy Policy,* 39(3): 1659-1668.

Specialized Solar Systems, 2012. *SSS Price List 250412 client*. [Unpublished document]. Available: sales@specializedsolarsystems.co.za.

Statistics South Africa (StatsSA), 2007. *Community Survey 2007* [Online]. Available: http://www.statssa.gov.za/community_new/content.asp?link=interactivedata.asp. [Accessed 5 July 2011].

Stattools, n.d. *Stattools for Intraclass Correlation for parametric data*. [Online] Stattools.net. Available: http://www.stattools.net/ICC_Exp.php [Accessed: 18 May 2012].

Tewari, D. & Shah, T. 2003. An assessment of South African prepaid electricity experiment, lessons learned, and their policy implications for developing countries. *Energy Policy*, 31():911-927.

The Carbon Neutral Company, n.d. 'Light it Up' *Improved Cooking Technique Project*. [Online] The Carbon Neutral Company. Available: http://www.carbonneutral.com/project-portfolio/light-it-up-improved-cooking-technique/ [Accessed: 28 June 2012].

The Energy and Resources Institute (TERI), 2008. *Supply of clean energy services to urban and peri-urban poor.* New Delhi: The Energy and Resources Institute.

Thorne, S. 1995. Electricity dispensers and affordable energy services. *Energy for Sustainable Development*, 1(6):30-32.

Tomlinson, M. 2006. From 'quantity' to 'quality': Restructuring South Africa's housing policy ten years after. *International Development Planning Review,* 28(1):85-102.

Townsend, A. 2000. Energy Access, energy demand and the information deficit. In The World Bank (eds.), *Energy and Development Report 2000*, p.8-24.

Tran, T. & Daim, T. 2008. A taxonomic review of methods and tools applied in technology assessment. *Technology Forecasting and Social Change* (75):1396-1405.

TsamaHUB, n.d. *About* [Online]. Available: http://www.tsama.org.za/. Accessed: 12 April 2012.

Turner, J. 1991. *Housing By People*. London: Marion Boyars.

United Nations Department of Economic and Social Affairs (UN-DESA), 2010. *Rethinking Poverty*. New York: The United Nations.

United Nations Development Program (UNDP), 2005. *Energy Services for the Millennium Development Goals.* New York: The United Nations.

United Nations Development Program (UNDP), 2007. Energizing the Least Developed Countries to Achieve the Millennium Development Goals: The Challenges and Opportunities of Globalization. *Making Globalization Work for the LDCs*, Istanbul, 9-11 July 2007. New York: The United Nations.

United Nations Energy (UN-Energy), 2005. *The Energy Challenge for Achieving the Millennium Development Goals.* [Online] UN-Energy. Available: http://www.un-energy.org/sites/default/files/share/une/un-enrg_paper.pdf. [Accessed: 4 July 2012].

United Nations Energy (UN-Energy), 2011. *Sustainable Energy For All.* [Online] UN-Energy. Available: http://www.un-energy.org/sites/default/files/share/une/sefa_concept_note.pdf. [Accessed: 4 July 2012].

University of Stellenbosch, n.d. *About the Hope Project* [Online]. Available: http://thehopeproject.co.za/hope/Pages/default.aspx. Accessed: 12 April 2012.

University of Stellenbosch, 2011. Stellenbosch University Hands out 200 Candles of Hope in Macassar. *News from Stellenbosch University* [blog] 8 June. Available at: http://blogs.sun.ac.za/news/2011/06/08/stellenbosch-university-to-hand-out-200-candles-of-hope-in-macassar/ [Accessed: 20 May 2012].

University of Witwatersrand (WITS) 2004. *Background Report 6: Specialist Papers. Study into Supporting Informal Settlements.* Johannesburg: WITS.

Van der Ryn, S. & Cowan, S. 1996. *Ecological Design*. Washington D.C.: Island Press.

Van Heusden, P. 2008. Discipline and the new 'logic of delivery': Prepaid electricity in South Africa and beyond. *In* McDonald, D. (ed.), *Electric Capitalism: Recolonising Africa on the power grid.* Cape Town: HSRC Press.

Van Horen, C., Eberhard, A., Trollip, H., Thorne, S. 1993. Energy, environment and urban poverty in South Africa. *Energy Policy,* 21(5):623-639.

Vera, I & Langlaois, L. 2007. Energy indicators for sustainable development. *Energy* 32(6):875-882.

Villagran, E. 2000. Key drivers of improved access – off-grid service. In The World Bank (eds.), *Energy and Development Report 2000*, p.52-59.

Visage, E. 2008. The supply of clean energy services to the urban and peri-urban poor in South Africa. *Energy for Sustainable Development*, 12(4):14-21.

Water and Sanitation Program (WSP), 2007. *Taking Water and Sanitation Services to the Urban Poor.* Washington, DC: The World Bank.

Watson, V. 2009. 'The planned city sweeps the poor away…': Urban planning and 21st century urbanization. *Progress in Planning*, 72(3): 151-193.

Wekesa, B., Steyn, G., Otieno, F. 2011. A review of physical and socio-economic characteristics and intervention approaches of informal settlements. *Habitat International*, 35(2): 283-245.

Wessels, B. forthcoming. *An institutional design for Solar Powered Informal Settlement energisation: The case of Enkanini, Stellenbosch.* MPhil. Stellenbosch University.

Wickson, F., Carew, A., Russell, A. 2006. Transdisciplinary research: characteristics, quandaries and quality. *Futures*, 38(9): 1046-1059.

Wilkinson, P. 1998. Housing Policy in South Africa. *Habitat International*, 22(3):215-229.

Willig, C. 2008. *Introducing Qualitative Research in Psychology*. London: McGraw-Hill.

Wolpe, P. 2011. FBAE Implementation Query, email to A. Keller [Online] 12 May. Available email: peta@sustainable.org.za

Wolpe, P. & Reddy, Y. 2010. Alleviating urban energy poverty in the informal sector: The role of local government. *Proceedings of "Overcoming inequality and structural poverty in South Africa: Towards inclusive growth and development"*, Johannesburg, 20-22 September 2010. Cape Town: Sustainable Energy Africa.

World Health Organisation (WHO), 2009. *Global Health Risks*. Geneva, Switzerland: The World Health Organisation.

Zuma, J. 2011. *State of the Nation Address By His Excellency Jacob G Zuma, President of the Republic of South Africa, at the Joint Sitting Of Parliament* [Online]. Available: http://www.info.gov.za/speech/DynamicAction?pageid=461&sid=16154&tid=27985. [Accessed: 19 February 2011].

Appendix A: An Introduction to Enkanini

A brief overview of the history, profile and core challenges of Enkanini follows, as a contextual introduction to the primary source of fieldwork activities. Enkanini is an informal settlement located on the western fringe of Stellenbosch, 2.6km from the center of town, and nestled between Kayamandi to its right (a neighbouring semi-formalised township), the Papagaaiberg Nature reserve to its left and the Plankenberg Industrial area below. The settlement was established in 2006, when 80 families of backyard dwellers from neighbouring Kayamandi successfully negotiated the occupation of a piece of adjacent land with the municipality. Soon afterwards, new arrivals settled in the area which, due to the resistance the local authorities posed, gave rise to its name, which literally translated means 'to force something'.

The Enkanini community is predominantly Xhosa-speaking, however some Sotho, Afrikaans and Somali residents also live there. Reliable demographic figures are not available, given that the community had not been enumerated yet, but estimates by residents range between 6 000 and 10 000 people. Unlike many other informal settlements, residents of Enkanini are young, almost all below 40 years old. This may be attributed to the function that Enkanini serves, namely a 'spillover' place for young adults trying to escape the control of their parents in adjacent Kayamandi. Alternatively, young people leaving rural areas visit their older relatives in other Cape Town informal settlements and, seeking to establish themselves independently, subsequently relocate to Enkanini.

To date, the municipality has only provided Enkanini residents with the most essential basic services. This is partly due to the illegal land tenure of the Enkanini (the community has an unexecuted standing eviction order) as well as the prioritisation of neighbouring Kayamandi, which itself has a services backlog and has been in existence for far longer. As such the entire community shares 12 taps and 60 toilets and has no legal electrical connections. Only those that can afford to pay exorbitant fees connect their shacks illegally with the use of electrical extension cords. The community relies on primary fuels such as candles, paraffin and fuelwood – the latter collected from the adjacent nature reserve. The lack of drainage, coupled with the steep topographical terrain and the removal of indigenous vegetation gives rise to torrents of turbid water, which run down the hillside during the long winter rains. None of the roads have tarred surfaces resulting in a muddy sludge in winter and dusty, windswept surfaces in summer.

Appendix B: The poverty dynamics of prepaid meters

During the mass-electrification programs of the 1980s and 1990s, a revolutionary technical development was underway (Van Heusden, 2008) which was to bring drastic changes to the electricity industry as well as supplier-customer relationships in South Africa: prepaid electrical metering[46].

The 1980 and 1990 socio-political landscape was characterised by service boycotts, a tactical form of opposition by black township residents who endeavoured to expand their fight against their apartheid oppressors (Thorne 1995). As such, the non-payment of services, including electricity, became one of the primary 'tools of the struggle' (Thorne 1995). It was this 'culture of non-payment' (Mehlwana, 1997; Wilkinson, 1998; Iliev, 2005) which the Qwa Qwa Development Corporation (a former 'homeland' in the Free State province) was seeking to address, when in 1985 it approached an electrical engineer at the South Africa Astronomical Observatory to design a system that could ensure revenue collection and manage disconnections and reconnection more effectively (Van Heusden, 2008).

Eskom, although initially only consulted on technical issues, saw the enormous potential of the meters in reducing the cost of manual meter readings, the cost of postal billing, as well as helping poor customers to prevent unanticipated consumption costs[47] (Tewari & Shah, 2003). "The conventional metering, in the absence of proper social attitudes to electricity, became a system demanding very high maintenance" (McGibbon, 2002 in Ruiters, 2008:257). For instance, the labour intensive task of managing disconnection and reconnections, was becoming dangerous, with some Eskom employees needing security details when performing these tasks (Ruiters, 2008). The parastatal thus decided to adopt the prepayment technology for its national electrification program to solve these challenges. Furthermore, as Gaunt (1989) proposed at the time, the large-scale electrification of domestic consumers, as envisaged, would not have been possible with conventional meters (Van Heusden, 2008). During the rollout of prepaid metering technology in the mid-1990s, "Eskom argued that blacks had the 'wrong social attitudes' for credit meters and prepayment would be a win-win" (Ruiters, 2007:493). Certainly, this view was not shared by the recipients, since the introduction of prepaid metering did not go unopposed (Thorne, 1995). Many considered prepaid metering technology to be of poor quality, differentiated from the service that white communities received (Tewari & Shah, 2003), and a sign of their lack of creditworthiness (Taylor, 2006 in Van Heusden, 2008). This encouraged Eskom and later local distributors to embark on large scale media campaigns in an attempt to popularise the negatively-perceived technology, by exhorting its virtues of convenience, budgetary manageability and ease-of-use (Tewari & Shah, 2003; Jaglin, 2008).

[46] For an overview of the functioning of the technology, see Iliev (2005) or Tewari & Shah (2003).

[47] In other words, to reduce the amount of bad debts by improving their revenue collection system

Appendix C: Pictorial chronology of the iShack construction process