

Activity 16: Research & Development



A REVIEW OF POTENTIAL INTERVENTIONS TO REDUCE HOUSEHOLD EMISSIONS FROM INFORMAL HOUSING FOR KWAZAMOKUHLE & EZAMOKUHLE



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EXECUTIVE SUMMARY

Eskom has commissioned a desktop analysis of potential interventions to reduce household emissions from informal housing for Kwazamokuhle & Ezamokuhle. The research has shown that emission reduction could be achieved by fuel switching; provision of new stoves; insulation of households; spatial heating; solar home systems and relocation to formal households.

For Eskom's AQO Project, interventions to reduce household emissions from domestic coal/wood burning will be rolled out in KwaZamokuhle and Ezamokuhle in the Mpumalanga Highveld. For formal dwellings the existing Eskom intervention includes the provision of a basic plus retrofit and a stove swap.

The basic plus retrofit intervention consists of insulation entailing the installation of a SPF ceiling system and draft proofing and electrical rewiring for the formal households. In contrast to formal households, informal housing is often poorly constructed from conductive materials and therefore are not well insulated. The structures are often of varying quality and layout, which makes the insulation of these structures challenging. As part of an offsetting project focused on informal housing in Lebohang, Mpumalanga 26 houses were retrofitted to improve the thermal performance of the structures. The project involved the insulation of the external walls using a PCF with the application of plaster cement and PVA paint to the exterior. Ceiling support and gypsum ceiling boards were installed and insulated with a SPF insulation.

A technical durability study on the retrofitted structures was conducted approximately one year after construction which indicated severe cracking in 58% households. Additionally, water damage was also widespread with extensive water damage occurring in approximately 30% of households. The water damage was evident by staining of the gypsum boards, with severe water damage causing sagging of the boards. Overall, the SPF was not fully protective of water leaks and the unstable roof structures were not able to support the weight of the SPF, causing cracking. The study concluded that maintaining the interventions in the long term would be challenging and that a larger scale rollout of the suite of interventions was not feasible.

Eskom's stove swap intervention for formal households entails the provision of electricity-based energy source with LPG backup. This includes a hybrid gas electric stove, LPG heater plus LPG cylinders and a compact fluorescent lamp. Additionally, this will require the removal and disposal of the coal stove. As informal houses are often poorly constructed and poorly insulated these houses require significant energy input to heat the houses to a comfortable temperature.

The results of this desktop Study have shown that whilst LPG has been successfully rolled out in low-income communities in formal housing, concerns remain on the ability of LPG to provide sufficient cost-effective heat input in the informal sector with poor house insulation and the associated perceptions of safety. The barriers for the rollout of LPG include the cost associated with LPG as well as an intermittent supply of LPG, which could cause households to revert to coal use. In the informal housing sector, the risk of reverting back to coal use could be higher due to the prevalence of adjacent or proximate informal structures that form part of the household.

It is clear from the analysis above that the current Eskom interventions of a basic plus retrofit and a stove swap with LPG is not directly transferable and will not work in the informal housing sector due to differences in the construction of the houses, cost associated with LPG and the fuel use patterns of the households. Interventions must be cognisant of the limitations imposed by the nature of housing in the informal sector. Informal houses are often built using conductive materials and can be poorly constructed, making the insulation of such households challenging. The households cannot be moved to cleaner energy such as LPG or electricity if the houses are not insulated, as these energy sources are much less efficient at space heating than wood or coal. Thus, it is recommended that the current Eskom interventions are not implemented in the informal housing sector.

Furthermore, it is evident that a multi-pronged integrated approach, including policy reforms, social compacts, public-private partnerships are pre-requisites if Eskom were to venture to sustainably address the emissions from informal houses.

1. BACKGROUND

1.1 ENVIRONMENTAL OFFSETS

Environmental offsets are alternative actions (investments or initiatives) made to measurably mitigate the residual negative environmental impacts of an industrial activity. An environmental offset is an action(s), designed to compensate for a negative environmental impact of resource use, a discharge, emission or other activity. Offsets should deliver a net sustainable development benefit, through an appropriately balanced assessment of the 5 Capitals: Natural/Environmental; Social, Human; Financial & Manufacture (Figure 1).

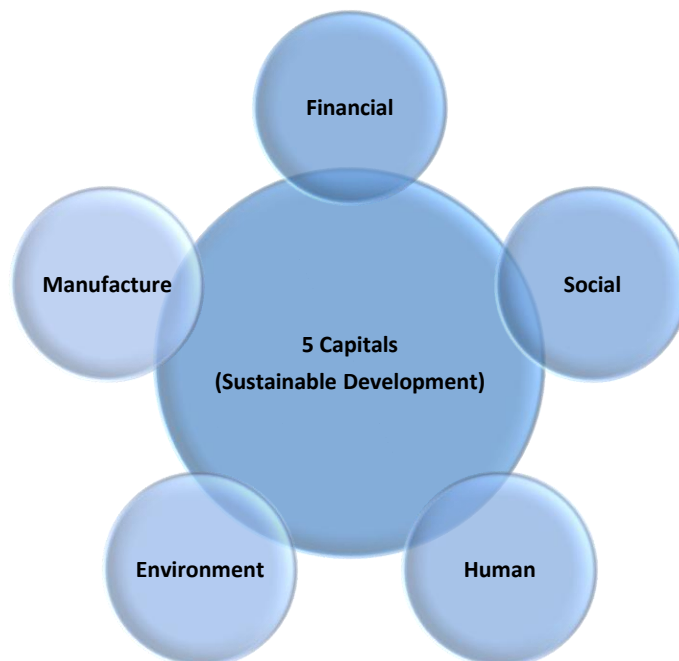


Figure 1: Five capitals approach to offsets

Offsets can be considered a form of mitigation, and part of a hierarchy of mitigation measures that should be applied to any development that has adverse environmental impacts. Proceeding from the top of the hierarchy, each measure must be fully considered before the next level of measures is considered. At the bottom of the hierarchy, offsets could be applied to mitigate the remaining adverse impact on the environment after appropriate avoidance, minimisation and rehabilitation measures

have been taken. Thus, the use of offset mechanisms is important in the various areas of air quality improvement, water use (consumption and discharge), greenhouse gas mitigation and biodiversity.

1.2 AIR QUALITY OFFSETS GUIDELINE

The Department of Environment, Forestry & Fisheries (DEFF) defines air emissions offsets as an intervention, or interventions, specifically implemented to counterbalance the adverse and residual environmental impact of atmospheric emissions in order to deliver a net ambient air quality benefit within, but not limited to, the affected airshed where ambient air quality standards are being or have the potential to be exceeded and whereby opportunities and need for offsetting exist (Notice 333 of 2016).

1.3 ESKOM'S APPROACH TO AIR QUALITY OFFSETS

DEFF's Air Quality Offset Guideline has shaped and informed Eskom's Air Quality Offsets Implementation Plan. This Plan has been based on a scientific process of feasibility studies, testing and demonstration, and on consultation with key stakeholders. Figure 2 illustrates the concept schedule for the phased implementation of Eskom's air quality offsets.

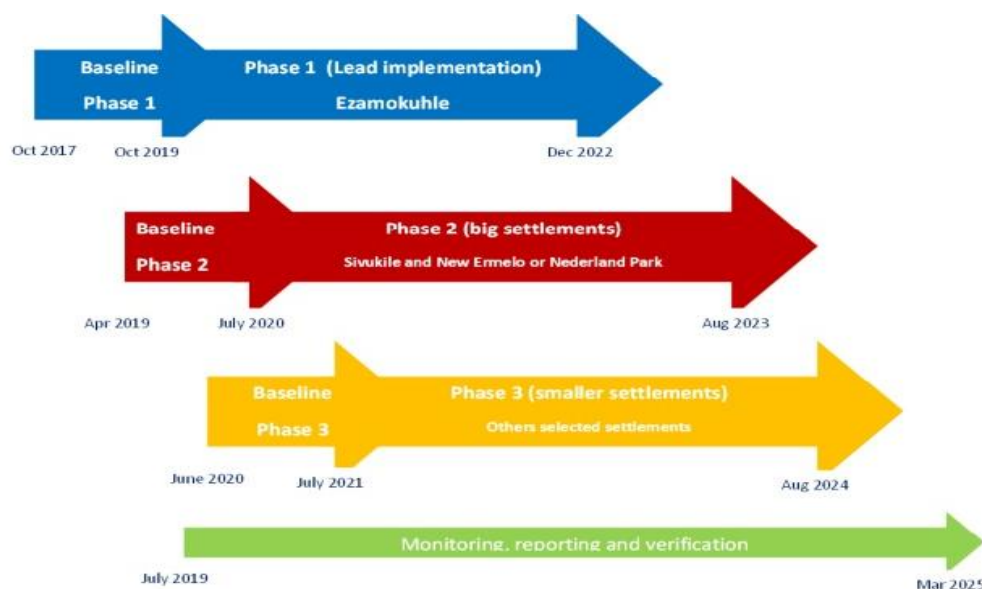
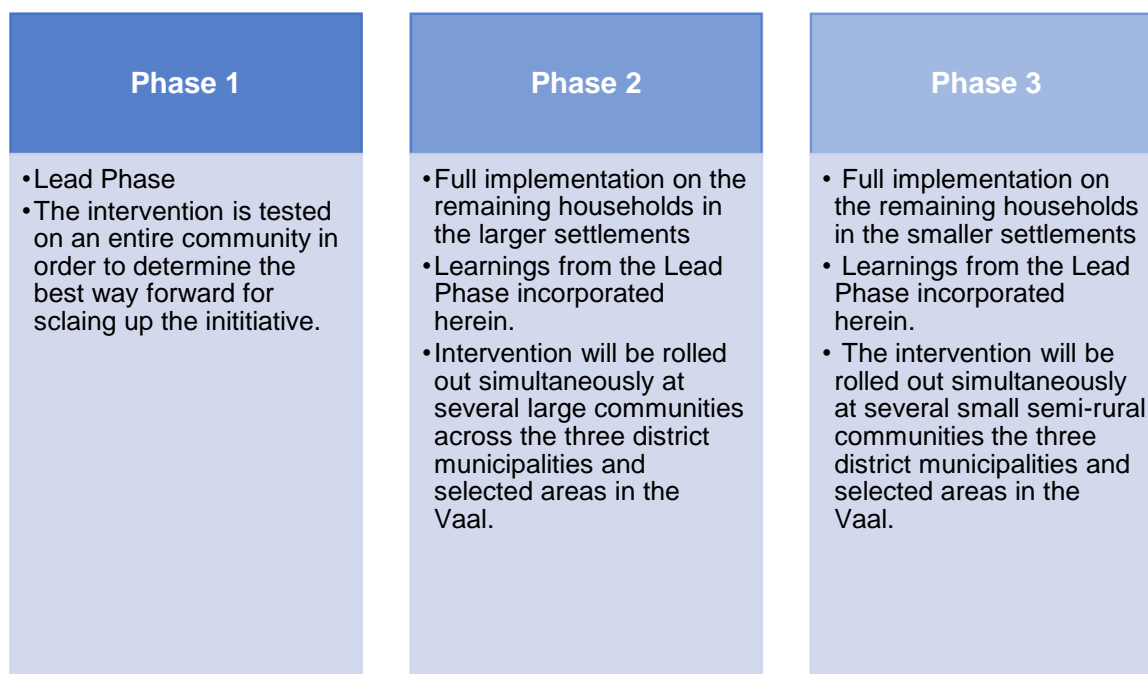


Figure 2: Concept Schedule for the implementation of Eskom's air quality offsets (Matimolane, 2020)

Eskom has adopted the phased approach (Figure 3) herein to increase the probability of success and to ensure that learnings from early phases are incorporated into the large-scale roll-out. (Matimolane, 2020).

Figure 3: Eskom’s Phased approach to the rollout of air quality offset interventions (Matimolane, 2020)



Eskom’s air quality offsets programme is designed to reduce human exposure to harmful levels of air pollution by reducing emissions from local sources, like domestic coal burning and waste burning. Thus, air quality offsets can improve ambient air quality in low-income communities in the vicinity of Eskom’s power stations. Eskom has developed air quality offset (AQO) implementation plans for Majuba Power Station (Ezamokuhle township); Hendrina Power Station (KwaZamokuhle township) and Lethabo Power station (Sharpeville).

1.4 ESKOM’S PLANNING, MONITORING AND VERIFICATION (PMV) PROJECT

For Eskom’s PMV Project, interventions to reduce household emissions from domestic coal/wood burning will be rolled out in KwaZamokuhle and Ezamokuhle in the Mpumalanga Highveld. For formal dwellings the intervention will be a thermal insulation retrofit and an electricity starter pack and installation. The intervention for informal dwellings still needs to be selected and tested. Interventions also need to be identified and implemented to improve air quality in Sharpeville,

Gauteng. Since domestic coal burning is less prevalent in Sharpeville, it is expected that a community-scale intervention, like reducing waste burning, will be more suitable there.

Air Resource Management (ARM) (Pty) Ltd has been appointed by Eskom to support the PMV services in support of the *Phase 1: Lead implementation* at: KwaZamokuhle; Ezamokuhle and Sharpeville. Its ARM (Pty) Ltd understanding that the overall objective *Lead Implementation Phase* is to benefit the specific local communities, minimize implementation risk, increase practical and scientific knowledge, and develop and refine monitoring, reporting and verifications processes. To achieve this, Eskom has included sixteen targeted work package Activities (Table 1) for these respective communities. This report focuses on Activity 16: Research and Development.

Table 1: Eskom PMV Activity Schedule

Activities	Kwazamokuhle	Ezamokuhle	Sharpeville
Activity 1: Preliminary air quality assessment		✓	
Activity 2: Gather Area intelligence		✓	
Activity 3: Rapid in situ assessment		✓	
Activity 4: Obtain ethical clearance		✓	
Activity 5: Census	✓	✓	✓
Activity 6: Community source survey		✓	
Activity 7: Fuel source survey		✓	
Activity 8: Household surveys		✓	
Activity 9: Annual (household/community) surveys and monitoring of project effectiveness	✓	✓	✓
Activity 10: Ambient air quality monitoring	✓	✓	✓
Activity 11: Conduct indoor air quality monitoring	✓	✓	
Activity 12: Atmospheric Dispersion Model	✓	✓	✓
Activity 13: Design of Intervention		✓	✓
Activity 14: Development of Database Reporting	✓	✓	✓
Activity 15: Strategic Assistance and offsets methodology	✓	✓	✓
Activity 16: Research and Development	✓	✓	✓

2. INTRODUCTION

Emissions from household solid fuel use have been demonstrated to have a negative impact on the health and wellbeing of communities. In KwaZamokuhle, solid fuel use is prevalent and studies have indicated that the most common energy carrier used in KwaZamokuhle is coal (Chidhindi et al 2018). The study further showed that domestic solid fuel burning contributes significantly to ambient PM concentrations in the study area.

A South African study analyzing the economic impact of various air quality initiatives found that technology interventions in the domestic sector would be the most efficient way to reduce healthcare costs associated with urban air pollution (Leiman et al 2007, 27). In recognition of the impacts associated with domestic fuel burning, the Department of Environmental Affairs published the 'Strategy to address air pollution in dense low-income settlements' under the National Environmental Management Air Quality Act 39 of 2004. The strategy emphasizes the need for a coordinated approach to ultimately move towards compliance with the National Ambient Air Quality Standards (DEA 2019, 1). The strategy includes a list of areas which may experience domestic emission related air pollution (DEA 2019, 8). The strategy proposes various interventions to be investigated such as solar technology, clean stoves, free basic electricity with efficient appliances, subsidized LPG, improving the energy efficiency of houses and the use of air quality offsets, amongst others.

South Africa has improved household access to electricity from an estimated 36% at the end of 1993 (DME 2001, ii) to an estimated 84% in 2016, significantly greater than the average for Sub Saharan Africa (World Bank 2018). Although there has been much progress in the provision of electricity to households, many still rely on traditional sources such as wood and coal (Israel-Akinbo, Snowball & Fraser 2018, 76). Informal households may not have access to electricity (Langerman et al 2018).

Interventions such as pollution limits or a phasing out strategy are not deemed suitable, as it is mainly poor households that are affected by household emissions (DEA 2019, 12). The use of these dirty fuels is driven by poverty, even though communities may recognize that emissions are detrimental to their health (DEA 2019, 12). Internationally, studies have recommended that interventions to reduce domestic use of dirty fuels should be accompanied by measures to address fuel poverty (Amann 2018, 48).

To ensure sustainability of interventions in the household sector, it is critical to utilise an integrated approach in addressing such emissions as those improvements would need sustained intervention over several years (Amann 2018, 4). In South Africa, the governmental strategy is cognizant of the

need to understand the needs of households in developing interventions to ensure sustainability (DEA 2019, 2).

Informal settlements and consequently informal housing represent some of the most marginalised and indigent people in society. It is estimated that about a billion or one-sixth of the world's population live in informal settlements and this number is forecast to double in the next decade or so (Global Health Equity, Issue 2, October 2019). Informal settlements, by their very nature, are unplanned, improvised human settlements without legal tenure systems and lack public infrastructure. In South Africa, informal settlements are not only a manifestation of our past spatial inequalities and unjust policies but persist even in the current post-democratic era, as a result of a surge of economic migrants who continue to pursue opportunity closer to economic hubs and urban areas.

Whilst informal housing presents some form of refuge to their occupants, they unfortunately lack basic infrastructure to support health and wellness including clean water, electricity, reliable and durable housing, sewage and waste management services. Globally, governments have responded to informal settlements and housing with a range of instruments not least being denial of their existence, and where their existence cannot be ignored, encouraging their expansion by making land available without any of the infrastructure spoken about or worse, by demolishing these settlements. However, even more scathingly, is the apathy of Governments to move informal settlements into the formal or affordable housing sector through some form of economic emancipation.

Informal housing is often poorly constructed from conductive materials and therefore are not well insulated. These houses require significant energy input to heat the houses to a comfortable temperature (Langerman et al 2018). Although various studies have investigated improvements that can be made to formal housing to improve thermal efficiency, fewer studies have assessed the interventions that may be applicable in the informal housing sector. A brief description of the interventions that may be applicable in the informal housing sector is given in the subsequent sections.

However, whilst these interventions will go some way to ameliorate the air quality in informal houses, it is clear that a multi-pronged approach, including policy reforms, social compacts, public-private partnerships are required if Eskom is to sustainably address the emissions from informal houses.

3. HOUSING IN THE INFORMAL SECTOR – “AN UNCOMFORTABLE REALITY”

3.1 DEFINITION OF INFORMAL SETTLEMENT

The United Nations (UN) Habitat, define informal settlements as residential areas where:

- i) inhabitants do not have security of tenure, land or dwellings that they are inhabiting;
- ii) there are either no or lack of basic services including water, electricity, sewage and waste management as well as infrastructure;
- iii) housing usually does not comply with the current planning and building regulations and is often in geographic and environmental hazardous areas (UN-Habitat, 2015).

3.2 CHARACTERISTICS OF INFORMAL SETTLEMENTS

As per the DHS (2009), the informal settlements are characterized by the following:

- i) **Illegality and Informality:** Residents live in a permanent state of legal and tenure insecurity. Without planning, informal settlements grow haphazardly and incrementally. The lack of planning makes service delivery difficult in informal settlements.
- ii) **Location:** Informal settlements generally spring up close to employment opportunities and sometimes on the urban periphery. However, the residents remain the most marginalized and indigent in society.
- iii) **Environmental Factors:** Informal settlements are often constructed on land which is not suitable for development for a variety of reasons such as unsuitable soil conditions, topographical constraints, environmental impacts, and within a 100-year flood-line.
- iv) **Restricted public sector investment:** The illegal status of informal settlements discourages public authorities from investment within informal settlements. As a result, informal settlements lack access to municipal services such as potable water, sanitation, roads, electricity, and street lighting.
- v) **Poverty and Vulnerability:** Informal settlement residents are generally poor with limited formal education. They are excluded from the formal labour market. This makes them extremely vulnerable.

- vi) Social stress: Poverty and poor living conditions breeds exploitation and gives rise to social stress which manifests in high levels of crime, domestic violence etc.

3.3 THE SOUTH AFRICAN POLICY LANDSCAPE ON INFORMAL SETTLEMENTS

South Africa has a progressive legal and policy framework governing the right to housing. South Africa has established a comprehensive state-subsidised housing programme, which seeks to redress the legacy of apartheid and grant eligible beneficiaries a variety of state-subsidised housing options (SERI, 2018). Despite these progressive policies, South Africa has between 1.1 and 1.4 million households or between 2.9 and 3.6 million people living in informal settlements (SERI, 2018).

3.3.1 THE CONSTITUTION

The Constitution provides for the right of access to adequate housing. It places an obligation on the state to progressively realise access to adequate houses by using legislation and other measures within its available resources. (DHS, 2021).

3.3.2 THE NATIONAL HOUSING CODE

The National Housing Code, 2009, sets the underlying policy principles, guidelines and norms and standards. This applies to all the government's housing assistance programmes, including those introduced in 1994 and the updated ones. Part 3 of the Code deals with the process and procedure for the in situ upgrading of informal settlements, especially regarding the provision of municipal grants and their ability to conduct the upgrading in a structured manner (DHS, 2021).

3.3.3 THE NATIONAL DEVELOPMENT PLAN

The NDP Vision 2030 focuses on the critical capabilities needed to transform the spatial economy and society. The plan highlights the need for a close link and integration between capabilities, opportunities and employment on social and living conditions (DHS, 2021).

3.3.4 THE SPATIAL PLANNING AND LAND USE MANAGEMENT ACT (SPLUMA)

The Spatial Planning and Land Use Management Act provides for a uniform system of regulating land development throughout the country. SPLUMA is a crucial intervention for integrating the various programmes and addressing housing challenges including redressing past spatial

imbalances and exclusions, including people and areas previously excluded and upgrading informal areas and settlements (DHS, 2021).

3.3.5 THE HOUSING ACT (ACT NO.107 OF 1997)

The Housing Act provides for the facilitation of a sustainable housing development process. Further, it lays down the general principles applicable to housing development in all spheres of government, including defining the functions of national, provincial, and local governments in respect of housing development (DHS, 2021).

3.3.6 BREAKING NEW GROUND (BNG), 2004

In September 2004, Cabinet announced a new housing policy - 'Breaking New Ground: A Comprehensive Plan for the Development of Sustainable Human Settlements' (BNG). The policy was formulated in response to the various gaps and criticisms of the earlier approach to low-income housing development (DHS, 2021).

3.3.7 PREVENTION OF ILLEGAL EVICTION FROM AND UNLAWFUL OCCUPATION OF LAND ACT, 1998

The PIE Act is an important piece of national legislation enacted to give effect to section 26(3) of the Constitution. The PIE Act safeguards against the eviction of unlawful occupiers living on both privately- and publicly owned land. The PIE Act applies to everyone who occupies land or property without the expressed or tacit consent of the owner or the person in charge of the land or property (DHS, 2021).

3.3.8 THE NATIONAL NORMS AND STANDARDS (2007)

In 1999, the Minister of Housing introduced the National Norms and Standards for the Construction of Stand-Alone Residential Dwellings in terms of section 3(2)(a) of the Housing Act. The purpose of the Norms and Standards was to provide minimum technical specifications and promote environmentally efficient design proposals (DHS, 2021).

3.3.9 2019-2024 MEDIUM TERM STRATEGIC FRAMEWORK

The MSTF specifically focuses on Sustainable Human Settlements and Improved Quality of Household Life (DHS, 2021).

3.3.10 PRIORITY HUMAN SETTLEMENTS AND HOUSING DEVELOPMENT AREAS PROGRAMME

The Priority Human Settlement Programme is the formulation of Policy Guidelines, Regulations and an Implementation Plan for the development of Priority Housing Development Areas (PHDA). PHDA's are declared by the Minister of Human Settlements to address specific housing needs to achieve sustainable human settlements through a process of intergovernmental cooperation, integrated planning and coordinated programmed implementation aimed at fast-tracking housing delivery (DHS, 2021).

3.3.10 NATIONAL ENVIRONMENTAL MANAGEMENT : AIR QUALITY ACT 39 OF 2004

This act regulates air quality and provides measures for the prevention of pollution and ecological degradation. It further aims to provide for national norms and standards regulating air quality monitoring, management and control by all spheres of government; for specific air quality measures; and related matters.

3.4 ENERGY USE PATTERNS IN INFORMAL HOUSES

The primary uses of energy in informal households is cooking, lighting, water heating and spatial heating. In a Gauteng Department of Agriculture and Rural Development (GDARD) commissioned feasibility study on alternative energy technology options for unelectrified informal settlements in Gauteng Province, the authors suggested that over a quarter of informal households located in densely populated low income communities remain unelectrified and even where there is access to electricity households continue to use multiple fuels in order to satisfy their energy needs and the fuels used are largely polluting and unsafe for humans (GDARD, 2015).

In many respects, this study and its findings on several Gauteng Townships including Ramaphosa Informal Settlement in Ekurhuleni Metropolitan Municipality, Slovo Park in the City of Johannesburg Metro, Bophelong Informal Settlement, Emfuleni Local Municipality in Sedibeng District Municipality and Zenzele Informal Settlement, Randfontein Local Municipality, West Rand District Municipality are proxies for other informal settlements in the country.

The study revealed that informal households generally have on average three occupants, two adults and one child. Nearly 30% of the residents are unemployed, 32% had some excess to the formal and informal economy and about a third of the residents are youth (GDARD, 2015)

Despite access to electricity (both legal and illegal connections), paraffin and candles were the main fuels used for lighting. For cooking and spatial heating, wood, coal, paraffin and LPG were identified as the main fuel sources.

From the survey responses¹, affordability, availability and safety were cited as the primary drivers for the choice of fuel used. Therefore, it is clearly evident that the choice and implementation of clean technology to address indoor air pollution in informal houses must at the very minimum take these factors into consideration to secure long term adoption and sustained use.

Table 2 Characteristics Driving Fuel Choices

Characteristic Driving Fuel Choice	Percentage of total sample
Safety	56 %
Availability	56 %
Clean	31 %
Reliability	42 %
Affordability	69 %

Source: Sample survey, SEA and Safe Energy 2015

4. INFORMAL HOUSING



Figure 4 Structure of Informal Houses

Informal housing in South Africa is generally constructed from unwanted materials, scrap or industrial byproducts or purchased materials. A combination of these materials can be utilised in constructing

¹ Sample survey, SEA and Safe Energy 2015

the dwelling (Peeters and Osman, 2005). A combination of timber, corrugated metal sheets and fibre cement is often used (Peeters and Osman, 2005). While corrugated metal is durable, lightweight and widely available, it offers poor insulation, resulting in hot dwellings in summer and cold conditions during the winter time (Peeters and Osman, 2005).

Generally, a timber frame is constructed to provide rigidity to the structure. Building materials such as corrugated iron or metal sheeting are nailed to the timber frame (Peeters and Osman, 2005; Nova Institute 2018). Roof support trusses are used to support corrugated iron roofs which are sloped (Nova Institute 2018). The structures can have interior walls constructed from Masonite sheeting or wooden sheeting that is fastened to the wooden structure. The floors are typically constructed using cement or compacted dirt (Nova Institute 2018). Wood and CGI sheets are the main materials, but appear in all sizes and conditions. Other materials used to build with are: bricks, tarpaulin, plywood, cardboard, plastic, newspapers and tires.

Generally, no structure can be recognized in the use of each material and all are differently sized and shaped, The structures have varying layouts, but mostly consists of square and rectangular sections combined into a single structure. Households can add to these structures over time, increasing the complexity of retrofitting the structure (Nova Institute 2018). The quality of the structures can vary significantly from well built and maintained to derelict structures and the quality of the building materials used is highly variable in shape, size and strength (Nova Institute 2018).

In many cases, electrical installations are not professionally installed and exposed plugs and connections can be found (Nova Institute 2018). Various studies have investigated the types of fuel burning devices utilized in electrified and non-electrified areas. Generally, two types of fuel burning devices are used in the area, namely mbaulas and cast-iron stoves (Loyd 2018). Previous studies have indicated that the most common energy carrier used in KwaZamokuhle is coal (Chidhindi et al 2018).

The inconvenient reality is that the unmet need for affordable or social housing continues to propagate the prevalence of informal houses. By its very nature therefore, informal house are make-shift structures, constructed of any manner of materials.



Figure 5 Structure of Informal Houses (Nova Institute 2018)

4.1 A VISUAL TIMESTAMP OF AN INFORMAL HOUSE BEING ERECTED

The pictures below illustrate the construction of a shack or informal house in Zandspruit (Stevens D 2019). It is evident that all types of material are used and the construction does not follow any norms and building regulation standards for rigidity and safety eg. the load bearing beams are made up of many improvised pieces and there is no consideration for insulation, ventilation or thermal efficiencies.





Figure 6: Construction of an Informal House in Zandspruit (Stevens D 2019)

4.2 THE AIR QUALITY CHALLENGE FOR INFORMAL HOUSES

Indoor Air Pollution (IAP) is a significant, often silent, but yet preventable threat to people's health and wellbeing. It often masquerades as an idiopathic cause of respiratory and other related disease and death ie it is challenging to always make a direct correlation between indoor air pollution and disease and mortality. However, scientific advancements and research the world over have now irrefutably shown the impacts of air pollution on people's health and wellbeing.

The combustion of wood, coal, paraffin, biomass and burning of household solid waste to satisfy the energy needs are the primary sources of direct localised exposure of informal housing inhabitants to $PM_{2.5}$, Ozone and other noxious pollutants (Figure 1a, b) (Wright et al. 2019) . It has been estimated that $PM_{2.5}$ and O_3 is associated with global mortality of 8.79 million people (Lelieveld et al., 2019), while Malley and colleagues (Malley et al., 2017) suggest that 3.4 million premature births globally might be associated with $PM_{2.5}$ concentrations.



Figure 7 Sources of Pollution in Informal Settlements ((Stevens D 2019)

5. INTERVENTIONS FOR THE INFORMAL HOUSING SECTOR

While various studies have investigated the interventions that can be applied to reduce solid fuel use in the formal housing sector. While some of these interventions are also applicable in the informal sector, the technologies may not be directly transferable to the informal sector due to differences in the construction of the houses and the fuel use patterns of the households.

Interventions must be cognisant of the limitations imposed by the nature of housing in the informal sector. The structures are of variable design and quality and other exhibit poor thermal insulation. The structures are highly variable and are often adapted and added onto over time. Structures belonging to the same household may be utilised for different purposes such as cooking and sleeping.

Figure 8 below shows the natural progression for upgrading informal houses.

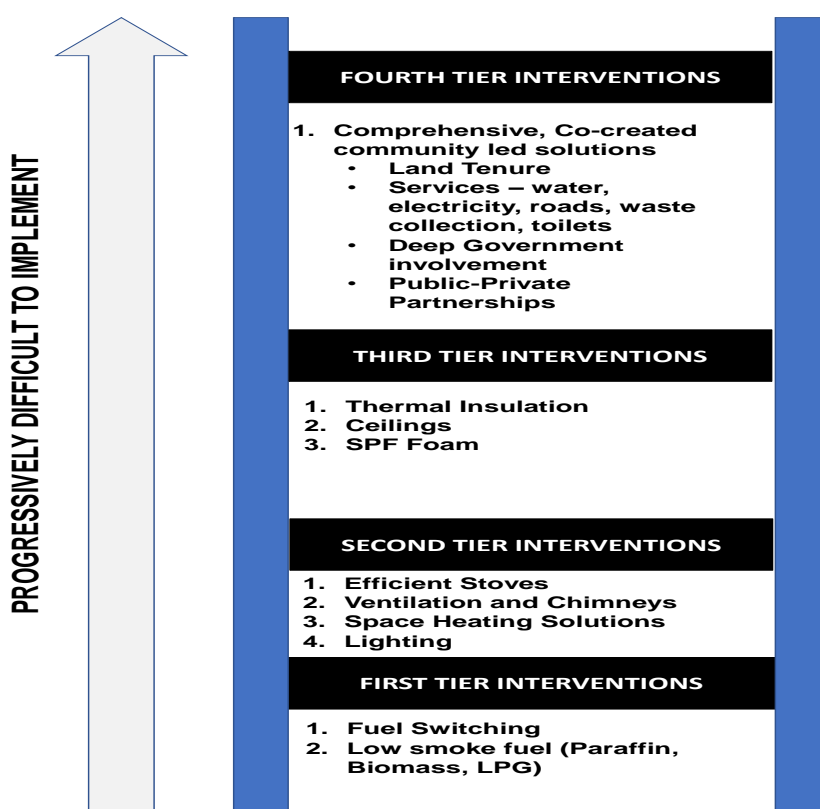


Figure 8 ARM Model of Air Quality Improvement Interventions

5.1 FUEL SWITCHING

Domestic emissions can be reduced by encouraging households to replace coal and biomass burning with cleaner fuels such as low smoke fuels and LPG. A study by Israel-Akinbo et al (2018; 76) examined how poor households transition from traditional energy carriers such as wood to modern energy carriers such as electricity, biofuels and liquefied petroleum gas.

The transition could follow an ‘energy ladder’ model whereby households move from traditional energy carriers to transitional and then to modern energy carriers as their income improves. The ‘energy stacking’ model indicates that households will utilize a combination of energy carriers on the upper and lower stages of the energy ladder, depending on their needs (Israel-Akinbo et. al. 2018, 77). The study found that for cooking, households will transition from traditional fuels to modern fuels as income rises in accordance with the energy ladder approach (Israel-Akinbo et. al. 2018, 81). In the case of energy usage for heating purposes, income was not a statistically significant determinant of energy usage, which means households will not necessarily switch to modern fuels as income rises,

in line with the energy stacking model (Israel-Akinbo et. al. 2018, 81). A study conducted by the Department of Energy came to a similar conclusion as their results indicated that poorer households relied on multiple sources of energy regardless of electrification status, which further points to an energy stacking model rather than the energy ladder theory (DOE 2012, 19).

As per Figure 9 below, the energy ladder suggests that households completely switch the fuels they use with increasing income whilst the energy stacking rejects that and suggests an alternative behavior of using multiple fuels at the same time.

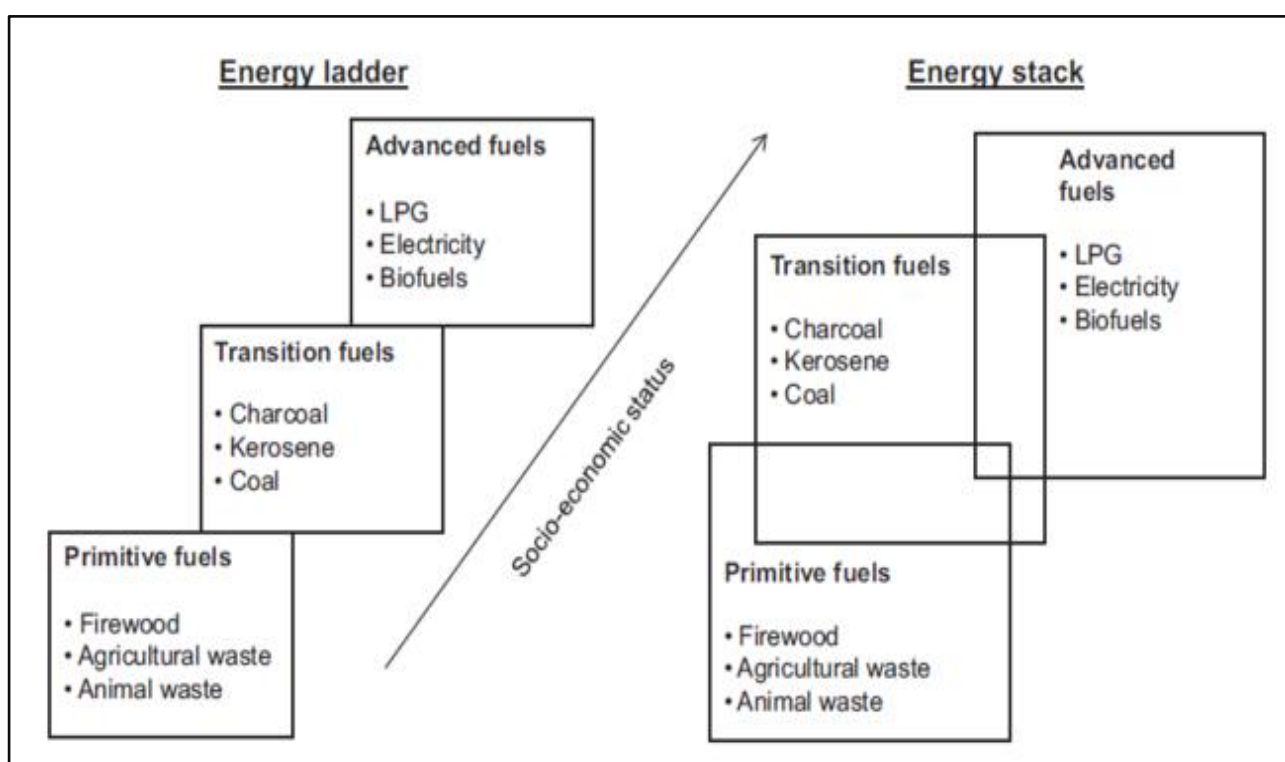


Figure 9 The Processes of Energy Transition (Kroon et al., 2013)

The alternative fuels that can be considered are discussed in the section following.

5.1.1. LOW SMOKE FUELS

Smokeless fuels do not produce smoke when burned. Smokeless fuels are usually solid fossil fuels, such as: anthracite, coke, and charcoal (Figure 10). Unlike bituminous coals they contain little impurities and so don't produce smoke when burned. Wood is not a smokeless fuel.

Anthracite has the highest amount of carbon and lowest amount of impurities of all domestic coals. Anthracite burns slowly with a blue flame. Because of its high carbon content, anthracite can be quite expensive when compared to ‘dirtier’ bituminous coals, but is better for the environment in terms of air quality.

For low smoke fuels (LSF) to be a viable alternative, they need to be socially acceptable to households as well as cost effective and must conform to technical requirements such as heat produced, speed of cooking and ease of ignition (Scorgie et al 2001, 11). Households were generally not opposed to switching to low smoke fuels, provided that the low smoke fuel should have similar heating characteristics to coal, should have a similar cost to coal and must be suitable for use in existing appliances (Scorgie et al 2001, 12). The fuel should be suitable for use in the stoves that consumers have access to and the potential emission reductions tested such appliances, as poor drafting conditions or suboptimal chimney designs could lead to less efficient burning of the LSF (Qase et al 2001).

In a survey conducted by Mdluli et al (2010, 2018), 28% of respondents indicated that they would utilize LSF if it burned longer than coal, produced the same amount of heat and also emitted less smoke, but that they would only consider purchasing such a fuel if they had seen and tested it (Mdluli et al 2010, 218). A study by Qase et al (2001) similarly concluded that, although there is general willingness to consider LSF, it was critical to for the fuel to perform at least as well as coal for space heating, cooking and water heating to gain acceptance. The fuel needs to light easily, should stay alight and provide as much thermal energy as coal (Qase et al 2001).

Devolatilised coal has been investigated as a potential LSF (Loyd 2019, Qase et al 2001). Coal undergoes partial pyrolysis which drives off the volatile materials, which renders a product that behaves like coal, but does not smoke on ignition. The LSF was tested in a 3000 household community in the Free State, South Africa and the study reports achieving positive air quality impacts in a short space of time (Loyd 2018). The benefit of using devolatilised coal is that existing coal distribution networks can be utilised to provide the product to consumers.

Various barriers exist for the transition to low smoking fuels such as the cost of LSF, acceptance by communities and proximity of suppliers to consumers whereas coal is widely available and seen as a cost effective source of energy. The LSF would require a distribution network to consumers (Qase et al 2001). The relative cost of the fuel and its availability are therefore critical considerations to prevent consumers from reverting to the use of coal. This may require the fuel to be subsidized, at least until general acceptance of the LSF is achieved.

Although low-smoke fuels have the potential to reduce emissions, they are not currently widely distributed (Langerman et al 2018). Continued technology scans for promising emerging LSF could identify a product that may be suitable for community testing. Previous study utilising devolatilised coal have shown promising results in reducing domestic emissions, but has not found widespread use.



Figure 10 Smokeless Solid Fuel

5.1.2. BIOGAS

Biogas can be utilized as a source of energy by the anaerobic digestion of organic waste. A byproduct of fertilizer provides additional benefits to the use of biogas. Smith et al (nd) conducted a financial and economic cost benefit analysis on the use of biodigesters in rural communities and found that, while bio digesters were not a financially feasible investment for rural households, there were substantial economic benefits attached to the use of bio digesters from a broader social point of view. The study found that the benefit related to lives saved due to improved air quality was a substantial benefit representing 65.8% of the economic benefit (Smith et al nd, 14).

A desktop study was conducted by Msibi and Kornelius (2017) to investigate the feasibility of biogas use in South African households. The study estimated the average energy needs of a household, calculated the biogas required to satisfy the household's energy needs and estimated the amount of waste required to generate the required biogas (Msibi et al 2017, 7). The study concluded that biogas was a feasible alternative for households with access to cattle and pig waste (Msibi et al 2017, 11). It was estimated that approximately 625 000 households could potentially benefit from the use of biogas, based on the availability of feedstock waste (Msibi et al 2017, 11). Due to the low volumes generated per household, it was found not to be feasible to feed biodigesters solely with chicken, human waste and food waste (Msibi et al 2017, 11).

The review of a pilot study conducted in the Eastern Cape Province indicated that approximately 65% of the installed bio digesters were not operational, mainly due to failures as a result of lack of operator skill or the failure of the digester biology (GIZ 2016 as cited by Semelane et al 2018, 2). For a biodigester to function optimally, the pH, category of organic feed material, frequency of feeding and water availability determine the health of the microbes (Semelanend, 2). There is therefore a need for training and support to biodigester beneficiaries to operate the biodigesters optimally and reduce failure rates. The study also found that bio digesters were not cost effective and that most biodigester installations in rural areas were donor funded (Semelanend, 3).

Biodigesters are more applicable in a rural area, where feedstock to the biodigesters such as manure is more readily available. Biodigesters furthermore require skill and continued care to ensure that the microbes function optimally.

However, if perfected, biogas can be an important technology for both waste management and as energy source. Kenya has successfully introduced the concept of biocentres. The biocentre technology provides multiple social, environmental and economic benefits to the communities residing in informal settlements. This technology provides dignified sanitation and responds to the high energy demand through supply of safe bio-gas for household application and natural compost for improved urban gardening hence improving household nutrition (Wasomga G, 2011).

The Indo-Swedish biogas collaboration across multiple cities in India between 2009 and 2011, were met with varying degrees of success (Swedish Energy Agency (2011)). The study identified several barriers that need to be overcome for successful biogas applications in informal settlements. These include:

- The difference between technical expertise and primary needs - In many cases, the most suitable system solution does not necessarily require the most advanced technology.
- Lack of standards, policies and means of control to promote the best socioeconomic application of biogas
- Community inclusion, participation and acceptance.



Figure 11 A Bio-sanitation facility at Katwekera village, Kibera

5.1.3. LPG

The replacement of solid fuel stoves with LPG largely eliminates particulate matter and SO₂ emissions. The use of LPG does not require the need for a backup energy carrier during power interruptions. For households residing in formal housing, switching from coal fired stoves to LPG gas and equipment showed positive results with most households preferring to use LPG (Nova Institute 2017).

During 2005/2006, low-income households in the Western Cape were encourage to swop two plate stoves for a two plate LPG stove and a gas cylinder to address frequent electricity disruptions. Surveys a year later indicated that 98% of the households were still using LPG for cooking purposes. The study indicated that LPG could be successfully rolled out to low-income households (Langerman et al 2018).

In order for fuel switching to LPG to be successful, recipients have to be able to continue LPG usage without reverting back to solid fuel. This intervention can only be successfully implemented if an LPG supply and distribution network is in place (EScience Associates and the Nova Institute 2013). Parallel use of LPG and coal stoves were found to occur where households used coal stoves in adjacent or proximate informal structures, with a significant association between having a mixed structure and the reintroduction of coal use (Nova Institute 2017).

The barriers for the rollout of LPG include the cost associated with LPG as well an intermittent supply of LPG, which could cause households to revert to coal use (Haines et al 2012). In the informal sector,

the risk of reverting back to coal use could be higher due to the prevalence of adjacent or proximate informal structures that form part of the household.

The reasons quoted in a number of studies for the general apathy of residents to switch to LPG include:

- Affordability of initial equipment costs
- Affordability of LPG cylinder refills
- Safety concerns
- Reluctance to switch from current fuel
- Availability and accessibility to refill cylinders
- Distance to purchase refills (last mile delivery)

Of these, affordability and safety ranked amongst the highest reasons for residents not wanting to use LPG.

Clearly, the above factors, need to be carefully considered for the implementation of LPG.

5.2 PROVISION OF NEW STOVES

Emission reductions can be achieved by replacing old, damaged and inefficient stoves with modern stoves with improved design. Various case studies have reported favourable cost-effectiveness and cost-benefit analyses for the improvement of cookstoves (Haines et al 2012). Bottom lit down drafting (BLDD) devices can be manufactured quite easily and be customized to suit the intended use. It was found that such devices run much cleaner than traditionally used imbaulas and had reduced CO emissions. It is also expected that the PM emissions would be reduced, but the reduction was not quantified by the study (Pemberton-Pigott et al 1999).

A study examining the uptake and continues use of improved cookstoves (ICS) surveyed 126 households in South Africa, Mozambique, Malawi and Zambia that had previously purchased or received a donated ICS. The study included urban, rural and peri-urban areas. The study found that the adoption of a new ICS did not result in the total replacement of traditional cookstoves and the use of multiple stoves, or stove stacking, was prevalent. This indicates that a single modern stove does not necessarily replace the utility from traditional methods for space heating cooking and water heating requirements (Pailman et al 2018). The study concluded that the consideration for the adoption of ICS such as the cost of the technology and smoke reduction differed from the drivers for sustained use, which centered on fuel saving and fuel cost and whether fuel was bought or collected.

Factors such as the availability of fuel, seasonality, cultural preferences and cooking practices further impacted on the choice of stove. These preferences can differ on household level (Pailman et al 2018).

Although improved solid fuel stoves have been demonstrated to reduce emissions, continued emission reduction is uncertain in cases where the emission reduction is dependent on the ignition method used. There is further uncertainty regarding the change in emissions as the stove ages (Langerman et al 2018). An investigation by EScience Associates and the Nova Institute (2013) noted that the use of coal and wood has been steadily declining and cautions that interventions such as new efficient stoves might slow down this declining trend, highlighting the need to evaluate potential unintended consequences of any intervention.

5.2.1 PROS AND CONS OF THE DIFFERENT COOKING TECHNOLOGIES

I. METHANOL/ETHANOL GEL STOVES



The stove is made up of a stainless steel body, one or two fuel chambers (canister) with capacities of between 0.5 - 1.2 litres each, and one or two plates using methanol or ethanol as fuel.

Figure 12 Methanol/Ethanol Gel

Advantages

- Safe, clean and more efficient than paraffin
- No odours
- High calorific value compared to more traditional fuels like paraffin and wood
- Sustainable supply of the technology and the fuel
- Potential for Small Medium and Micro-sized Enterprises (SMME) development for fuel distribution in canister, since refueling is on the basis of exchange of canisters that are in easily-manageable sizes
- Stove is easy to use
- Operating costs are comparable to the going rate of paraffin that is currently in use.

II. BIOMASS COOK STOVES



Figure 13 Biomass Cookstove

The stove is made up of a galvanised or stainless steel base with a ceramic, heat-absorbing liner. It comes with a stainless steel grill and a stainless steel pot spacer. The liner is heated by either wood or charcoal. Once hot, it optimises the heat. The clay liner significantly reduces burning fuel required, which in turn reduces smoke emissions; decreasing costs, carbon footprint and health risks. It is much safer than paraffin or gas stoves and uses only 7-15 pieces of charcoal to cook a meal for a family.

ADVANTAGES

- Efficient
- Uses familiar and available fuels
- Compact and mobile.

DISADVANTAGES

- Although more efficient, still uses polluting fuels such as wood and coal

III. LPG STOVES



Figure 14 LPG Stove

The stove is made up of a stainless steel body with two plates. It connects to a separate gas cylinder via a hose and flow regulator.

ADVANTAGES

- Convenient, clean and relatively safe
- High calorific value reduces cooking time significantly.

- LPG is a clean burning fuel and reduces indoor air pollution by as much as 90% in comparison to burning traditional fuels
- LPG stoves quickly supply heat and work more efficiently than wood and paraffin stoves. The simple and precise regulation simplifies the cooking process and can save time.

DISADVANTAGES

- Reliance on distributor and distribution network
- LPG tank management is difficult (storage, transportation) due to their sizes.
- LPG costs are high
- Perceived safety concerns with gas

IV. SOLAR STOVES



The stove is made up of a rugged plastic body, with space inside for several cooking pots. The Perspex lid allows light in, but traps heat within the cooker. The cooker works best with black pots.

Figure 15 Solar Stove by Sunstove

ADVANTAGES

- Free to operate – uses the sun
- Safe
- Needs little supervision
- Can cook entire meal at once
- Provides better air quality indoors

DISADVANTAGES

- Relies on the sunlight for cooking (not predictable, can only cook during the day), and also makes it difficult to use during winter months or rainy days
- Cooking takes significantly longer than conventional methods

- Cannot be used indoors.

V. HOT BOX OR WONDERBAG



Figure 16 Wonderbag

The hot box or wonderbag is an insulated cooker made up of two poly-cotton bags filled with expanded polystyrene (EPS) balls, into which a pot of food brought to the boil can be placed. The hot box uses the principle of thermal insulation to continue the cooking process without needing additional heat.

ADVANTAGES

- Free to operate
- Safe and convenient
- In the many households where paraffin or coal is used for cooking, a direct improvement in indoor air quality can be expected as does not emit any health damaging pollutants.
- Needs little supervision
- Low capital cost
- Reduces the amount of fuel needed for cooking (estimated to save up to 30% of total fuel costs associated with cooking with paraffin alone)
- Meals can be safely prepared ahead of time

DISADVANTAGES

- Does not eliminate use of polluting fuels entirely

- Limited to type of foods that can be cooked

5.3 INSULATION OF HOUSEHOLDS

Informal houses by virtue of their design and construction, are very thermally inefficient. Inhabitants can spend up to 20% of their disposable income on space heating by burning bio-fuels like wood, coal and paraffin during winter months. This produces indoor pollution, and the pollution levels in informal low-cost houses are up to 10 times higher than prescribed by the World Health Organisation. The solution to this problem is to make the houses more energy efficient by insulating them (Matthews et al, 1998).

As part of an offsetting project focused on informal housing in Lebohang, Mpumalanga, South Africa, 26 houses were retrofitted to improve the thermal performance of the structures. The project involved the insulation of the external walls using a Polystyrene Cement Foam (PCF) with the application of plaster cement and PVA paint to the exterior. Ceiling support and gypsum ceiling boards were installed and insulated with a Spray Polyurethane Foam (SPF) insulation (Nova Institute 2018). Households were further provided with either an improved solid fuel stove or LPG devices in exchange for existing solid fuel combustion devices.

A technical durability study on the retrofitted structures was conducted approximately one year after construction. The structures were inspected visually and physically and therefore underlying structural issues were not included in the assessment. Cracking of the plastering was evident, with 58% of households experiencing more severe cracking. There were a few households where the PCF walls were cracked and two houses displayed cracks that may lead to breakages in future. The study indicated that the PCF does not have its own structural integrity and movement in the original structure can lead to cracks and breakages. Household activities such as enlarging homes or re-installing stoves can further compromise the integrity of the intervention (Nova Institute 2018).

Water damage was also widespread with extensive water damage occurring in approximately 30% of households. The water damage is evidenced by staining of the gypsum boards, with severe water damage causing sagging of the boards. In some cases the ceiling boards were pulling out of the fasteners and some ceilings moved vertically when pressure was applied. The water damage occurred where roofs were at their lowest point, where depressions form or where adjoining rooms meet and are not properly sealed. Overall, the SPF was not fully protective of water leaks and the unstable roof structures were not able to support the weight of the SPF, causing cracking (Nova Institute 2018).

The study concluded that although the participating households experienced an improvement in quality of life aspects such as improved thermal comfort and reduced water roof leaks, maintaining the interventions in the long term would be challenging and that a larger scale rollout of the suite of interventions was not feasible (Nova Institute 2018).

Informal houses are often built using conductive materials and can be poorly constructed, making the insulation of such households challenging. The households cannot be moved to cleaner energy such as LPG or electricity if the houses are not insulated, as these energy sources are much less efficient at space heating than wood or coal (Langerman et al 2018).

5.3.1 THE CHALLENGES WITH INSULATING INFORMAL HOUSES

The purpose of informal dwellings is to provide affordable and functional shelter to its inhabitants. As a result, informal houses are poorly constructed, use arbitrary and varying construction material, and do not follow any building standards. The pictures below, showing the construction of informal homes are from the work undertaken by NOVA in Lebohang Township in Mpumalanga on behalf of Sasol (Nova Institute 2018).



Figure 17 The wooden substructure of vertical poles and horizontal planks, clad with corrugated iron roof and Masonite inner walls (Nova Institute 2018).

The current available and tested technologies for ceiling and insulation work can require that the informal houses be structurally reinforced. This influences cost and schedule to complete the exercise. It is almost impossible to plan the level of interventions required to stabilise, reinforce and improve the houses as each dwelling is unique and different in its construction, Without this level of pre-intervention, NOVA has demonstrated that the probability of success and continued reliability of PCF and SPF is significantly diminished (Nova Institute 2018). The pictures show the post

implementation condition of the ceilings, PCF and SPF as a result of water ingress, structure movements, dwelling expansions by the resident etc.



Figure 18 Post-insulation and ceiling damages

5.4 SPATIAL HEATING

In informal houses, stoves used for cooking also provide spatial heating of the homes. It is important that any energy efficient and clean technology intervention minimizes the need for multiple solutions for ease of adoption by residents. It is important to note that successful insulation is a precursor for spatial heating interventions.

I. ROCKET STOVES



Figure 19 Post-insulation

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, dung, other biomass fuels.

II. LPG Heaters



Figure 20 LPG Heater

The heater is made up of a metal housing with the heating elements at the front. The housing holds the LPG cylinder, which connects via a hose and flow regulator.

5.5 SOLAR HOME SYSTEMS

Solar home systems present a clean technology solution in the energy stacking model. The efficacy of solar lighting solutions are well established. Incrementally scalable solar photovoltaic DC multigrid, off-grid and mini-grid technologies are emerging as potential solutions for clean energy in informal settlements. The financial viability and adoption of Solar PV has not been demonstrated at scale.

The DC Multigrid System



Figure 21 DC Multigrid System

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, battery storage (Keller A, 2012).

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, televisions, freezers, microwaves etc can be added by adding PV panels and battery capacity (Keller A, 2012).

The advantages of such a system include:

- 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 is costly
- Can be implemented independent of government
- Low level of technical sophistication – easy to repair, does not require skilled labour to install
- Prepayment system options enable revenue collection for implementers
- Scalable and modular – in line with a flexible incrementalistic approach (Keller A, 2012).

The Free Basic Alternative Energy (FBAE) Policy provides that unelectrified communities unable to access the FBE subsidy could access a subsidized non-exhaustive list of energy carriers (including coal, paraffin, LPG and Bio ethanol gel) through the FBAE subsidy. However, whilst municipalities are tasked with the implementation of the policy, they have not really adopted this (Keller A, 2012). If the FBAE is to be adopted like it should, the solar PV solutions may be a feasible option for electrification of informal houses.

5.6 RELOCATION TO FORMAL HOUSING

In many middle-income countries, the in-situ upgrading of informal settlements has become standard practice, but has not found wide adoption in areas located in Asia and Africa (Haines et al 2012). The most successful upgradings have been where government agencies have worked with organizations within the communities to design and organize the work to be done (Haines et al 2012).

A study by Leuker (2019) investigated the impact of housing design for the improvement in air quality for a resettlement in Mumbai, India. The study identified air quality improvement mechanisms that had the potential to reduce annual average pollutant exposure of household occupant by more than 95% when using passive interventions such as sealing of the building, cook zone partitioning and the installation of high-efficiency particulate air filters. Kitchen extraction fans were modeled to further reduce PM exposure.

Burgos et al (2013) studied the air quality benefits of relocating families from informal housing to public housing in Santiago, Chile. The study found that housing interventions significantly reduced indoor PM_{2.5} concentrations and that outdoor PM_{2.5} was the most significant predictor of indoor PM_{2.5} exposure, highlighting the need for community wide interventions. The fuels that households used for water heating was also found to impact on indoor air quality. There was found to be no solid fuel use in the public housing, whereas charcoal, wood and waste were used for home heating in the informal houses.

Housing design is key in determining thermal comfort. The Witsand Community Energy Project in Witsand, Western Cape, South Africa utilised passive measures such as passive solar and wind benefits to construct housing to upgrade the informal settlement. The temperature measurements indicated improved thermal comfort when compared to nearby informal housing (Haines et al 2012).

Peeters and Osman (2005) investigated possible improvements to the design of informal housing to improve the quality of housing in Mamelodi, Gauteng. They concluded that solutions were not a one size fits all approach and should be cognisant of the realities of the local conditions. Factors such as the use of different building materials, building orientation, window size, exterior colour and insulation could all potentially improve energy efficiency.

Venter et al (2019) used data from 18 projects across South Africa and showed that regenerative development using locally available waste such as eco-bricks and waste tires could improve the insulation and safety of informal housing.

A cementitious mixture composed of power station fly ash, lime and gypsum was developed in India as an alternative building material to clay fired bricks and cement brick to reduce the environmental impact of the traditional brick manufacturing process. The bricks can be cast and air dried and their compressive strength was found to increase with time (Niranjan et al 2015).

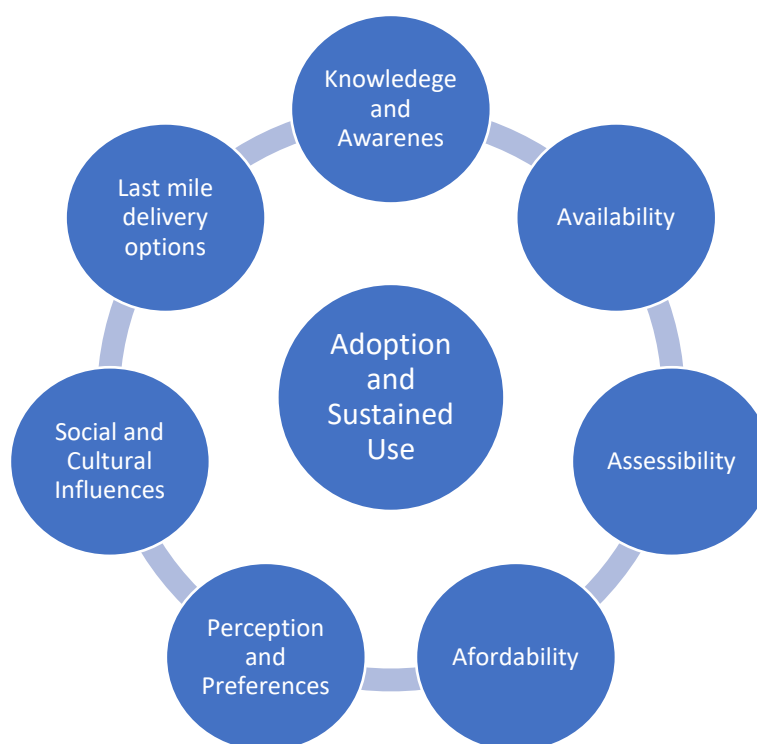
South Africa is familiar with the concepts of Temporary Relocation Areas (TRA) and Incremental Development Areas (IDA). TRAs and IDAs are intended to be located on land suitable for long term upgrading ie. once their function has been fulfilled, the sites will never be cleared. IDAs may be regarded as residential transit areas eg for people waiting for RDP homes and once one group moves into their new homes, another group takes their place (Keller A, 2012).. This is a novel concept but requires multiple stakeholder commitment.

6. PROPOSED APPROACH FOR SUCCESSFUL CLEAN TECHNOLOGY INTERVENTIONS

6.1 UNDERSTANDING THE CHALLENGES

Figure 21 below highlights some of the constraints that any intervention will need to overcome in order to secure successful adoption of the solution. If these are not adequately addressed, reverse switching from clean to polluting fuels is a very real risk.

Figure 22 Factors affecting successful adoption



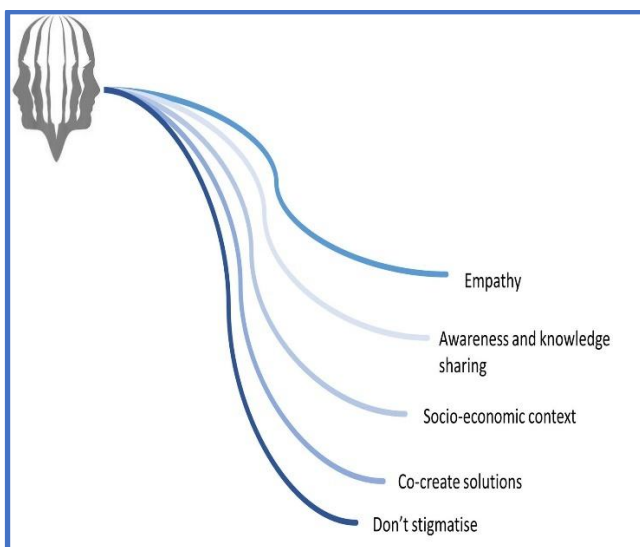
- I. **KNOWLEDGE AND AWARENESS** – make the communities part of the solution. Allow flexibility and co-creation.
- II. **AFFORDABILITY** – is probably the single most important determinant for successful adoption. Any new intervention cannot not be more expensive than the current and implementers must be guarded against changes in both macroeconomic and socioeconomic conditions that will rapidly catalyze reverse switching.
- III. **ACCESSIBILITY/AVAILABILITY/LAST MILE DELIVERY** – Solutions such as clean fuels must be easily accessible eg. set up local distribution networks and promote SMMEs within

the settlement for LPG. Last mile delivery refers to the very last step of the delivery process when a service or good is moved from a hub to its final user. This must be simple, streamlined, accessible and available to enhance the customer experience and by inference their continued adoption of a clean technology.

- IV. **SOCIAL AND CULTURAL INFLUENCES AND TRADITION** - drives perception and preferences. Engage communities on preferences when designing solutions.

6.2 PATHWAYS TO SUCCESSFULLY ADDRESSING INDOOR AIR POLLUTION

I. HUMANISING THE PROBLEM



There is often a tendency to forget that there are real people with real problems and real lived experiences when addressing Indoor air pollution in informal houses. Solutions are designed from an outsider lens and are therefore not always adopted and sustained.

Humanising the problem, requires one to place oneself in the shoes of residents of informal houses and to be empathetic in order to co-create lasting sustainable solutions.

Figure 23 Humanising the problem

II. COLLECTIVITY

Approach upgrading from a collective approach ensures that divergent interests are properly understood and incorporated into the upgrading process. Build effective partnerships with the community and local government etc (Keller A, 2012).

- III. **UNLEASH LATENT CREATIVITY** - Collective processes stimulate discussions and problem-solving which inevitably inspire creative solutions to some fundamental problems (Keller A, 2012).

-
- IV. **HOLISTIC AND INTEGRATED** – Effective upgrading needs to integrate social, environmental and economic aspects of a settlement in full cooperation with the communities (Keller A, 2012).
- V. **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.

7. CONCLUSION

Emissions from household solid fuel use have been demonstrated to have a negative impact on the health and wellbeing of communities. In both eZamokuhle and KwaZamokuhle, solid fuel use is prevalent and studies have indicated that the most common energy carrier used in these townships is coal which contributes significantly to ambient PM concentrations in the study area. While various studies have investigated interventions that can be applied in the formal housing sector to reduce solid fuel use, fewer studies have examined the technologies available in the informal sector.

Emission reduction can be achieved by switching households from dirty fuels to alternative fuels. Factors such as cost, fuel performance and distribution will impact on how well the alternative fuels is accepted for use in communities. While studies have shown that reduced emissions can be achieved using low smoke fuels (LSF), they have not found widespread use in South Africa. Devolatilised coal has shown promise as an alternative fuel. LPG has been successfully rolled out in low income communities in formal housing, concerns remain on the ability of LPG to provide sufficient cost-effective heat input in the informal sector with poor house insulation. The challenge with fuel switching is that households could revert (reverse switch) back to coal use, particularly due to fuel cost and availability considerations.

Improved cooking stoves have the potential to reduce household emissions, but concerns remain about the emissions from these devices as they age. Furthermore, these stoves are likely to be less effective if their efficiency depends on the correct lighting procedure and other factors such as adequate draft through the stove flues.

In many middle-income countries, the in-situ upgrading of informal settlements has become standard practice and the most successful upgradings have been where government agencies have worked with organizations within the communities to design and organize the work to be done. This is particularly important in the South African context, where small local businesses can benefit from the upgrading projects. Once upgraded, these households could be more successfully transitioned to cleaner fuels. The use of locally available material for the upgrading of structures should be investigated to reduce the cost of the upgrades,

The air quality that households are exposed to not only depend on the energy carriers utilised by the household, but also by the burning practices of surrounding households. Interventions in informally housed communities therefore have to address the fuel burning practices of a large portion of the community to be effective.

Having regard that many informal settlements are often located on illegal and unsuitable land, resettlement and relocation of informal settlements is a possible option for settlement upgrades. However, in the South African context, this is always a tenuous and contentious issue and needs multi-stakeholder involvement to successfully implement. However, the concepts of temporary relocation areas (TRAs) and Incremental Developmental Areas (IDAs) have been conceived in Cape Town for example. IDAs are intended to be located on land suitable for long term upgrading and may be regarded as residential transit areas eg. for people waiting for RDP houses, as one group moves into new RDP homes, another group takes their place. IDAs have minimal services but sufficient to address indoor air pollution.

8. RECOMMENDATION

For Eskom's AQO Project, interventions to reduce household emissions from domestic coal/wood burning will be rolled out in KwaZamokuhle and Ezamokuhle in the Mpumalanga Highveld. For formal dwellings the existing Eskom intervention includes the provision of a basic plus retrofit and a stove swap.

8.1 BASIC PLUS RETROFIT FOR INFORMAL HOUSEHOLDS

The basic plus retrofit consists of insulation entailing installation of an SPF ceiling system and draft proofing and electrical rewiring for the formal households. In contrast to formal households, informal housing is often poorly constructed from conductive materials and therefore are not well insulated. The structures are often of varying quality and layout, which makes the insulation of these structures challenging. As part of an offsetting project focused on informal housing in Lebohang, Mpumalanga, South Africa, 26 houses were retrofitted to improve the thermal performance of the structures. The project involved the insulation of the external walls using a Polystyrene Cement Foam (PCF) with the application of plaster cement and PVA paint to the exterior. Ceiling support and gypsum ceiling boards were installed and insulated with a SPF insulation.

A technical durability study on the retrofitted structures was conducted approximately one year after construction which indicated severe cracking in 58% households. Additionally, water damage was also widespread with extensive water damage occurring in approximately 30% of households. The water damage was evident by staining of the gypsum boards, with severe water damage causing sagging of the boards. Overall, the SPF was not fully protective of water leaks and the unstable roof structures were not able to support the weight of the SPF, causing cracking. The study concluded that maintaining the interventions in the long term would be challenging and that a larger scale rollout of the suite of interventions was not feasible.

8.2 STOVE SWAP

Eskom's stove swap for formal households entails the provision of electricity-based energy source with LPG backup. This includes a hybrid gas electric stove, LPG heater plus LPG cylinders and a compact fluorescent lamp. Additionally, this will require the removal and disposal of the coal stove.

Informal houses are often built using conductive materials and can be poorly constructed, making the insulation of such households challenging. These houses require significant energy input to heat the houses to a comfortable temperature. This results of this desktop Study has shown that whilst LPG has been successfully rolled out in low-income communities in formal housing, concerns remain on the ability of LPG to provide sufficient cost-effective heat input in the informal sector with poor house insulation and the associated perceptions of safety. The barriers for the rollout of LPG include the cost associated with LPG as well as an intermittent supply of LPG, which could cause households to revert to coal use. In the informal housing sector, the risk of reverting back to coal use could be higher due to the prevalence of adjacent or proximate informal structures that form part of the household.

It is clear from the analysis above that the current Eskom interventions of a basic plus retrofit and a stove swap with LPG is not directly transferable and will not work in the informal housing sector due to differences in the construction of the houses, cost associated with LPG and the fuel use patterns of the households. Interventions must be cognisant of the limitations imposed by the nature of housing in the informal sector. Informal houses are often built using conductive materials and can be poorly constructed, making the insulation of such households challenging. The households cannot be moved to cleaner energy such as LPG or electricity if the houses are not insulated, as these energy sources are much less efficient at space heating than wood or coal. Thus, it is recommended that the current Eskom interventions are not implemented in the informal housing sector.

Furthermore, it is clear that a multi-pronged integrated approach, including policy reforms, social compacts, public-private partnerships are pre-requisites if Eskom were to venture to sustainably address the emissions from informal houses.

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ANNEXURE 1

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