
# ENERGY RETROFITS IN THE REPUBLIC OF SOUTH AFRICA

RETROFITTING BUILDINGS FOR ENERGY EFFICIENCY

Author: Adérito Almeida
Teacher: Ing. Karel Struhala Ph.D.

2019/ 2020

BH055 Failures and Reconstruction-

**Abstract.** This report is mainly based in four different data sources all based in energy efficiency and its implementation in new as well old buildings.

They are namely: Clean Energy Solutions – an international institute (supported by UN-Energy and the Clean Energy Ministerial), which helps governments design and adopt policies and programs that support the deployment of clean energy technologies;

Bridging Information Gap of Energy Efficiency in Buildings (bigEE) - an international initiative of research institutes for technical and policy advice and public agencies in the field of energy and climate, co-ordinated internationally by the Wuppertal Institute of Germany and implemented nationally by South African National Energy Development Institute (SANEDI). Its aim is to develop the international web-based knowledge platform called http://www.bigee.net for energy efficiency in buildings, building-related technologies, and appliances in the world's main climatic zones, which will be discussed in the future pages of the report;

The last source that enriches this work comes from a scientific article covering Barriers to Retrofitting Buildings for Energy Efficiency in South Africa.

**Key words:** Buildings, Efficiency, bigEE, SANEDI, Barriers, Retrofitting, South Africa, Clean Energy Solution Center.

# Table of Contents

# 1 Introduction

South Africa's National Energy Efficiency Strategy, released in 2005, seeks to reduce energy intensity in several sectors to foster economic growth without equivalent growth in carbon emissions and energy consumption. The strategy presents energy efficiency targets for the industry and mining, commercial and public, residential and transport sectors [1]. Within this context, in 2013 South African National Energy Development Institute (SANEDI) partnered with the Clean Energy Solutions Center via its Ask an Expert service to enable energy efficiency in the buildings sector. In particular, the Solutions Center supported development of the Regulations on Allowance for the Energy Efficiency Savings legislation designed to provide a framework for effective energy efficiency regulation, incentives and energy reduction targets for South Africa's commercial buildings sector [1].

| | SOUTH AFRICA COUNTRY PROFILE |
|---|---|
| Total area | 1,221,037 km$^2$ |
| Population density | 42.4/km$^2$ |
| Energy supply | 72% coal, 22% oil, 3% natural gas, 3% nuclear, <1% renewables |
| Energy use | 37% manufacturing, 31% transport, 9% residential, 7% commercial, 8% mining, 8% other |
| Electrification rate | 73% |
| Installed generation capacity | 90% coal, 5% nuclear, 5% hydro |
| Fuel imports | 110,000 barrels/day petroleum |

*Figure 1 - South Africa Country Profile 2017 [1]*

The importance of energy to the growth and development of any nation (developed and developing) cannot be disputed. When we compare the other sectors of the economy, buildings are known to have a high percentage of energy consumption, although the rate of each country and region differs. For example, the industrial sector is the largest consumer of energy at almost 62% while the domestic/household consumption account for 20% of the total energy consumption in South Africa.[2]

The South African government revised the National Energy Efficiency Strategy (NEES) to reduce the energy consumption significantly and to foster energy efficiency. South Africa ratified the Kyoto Protocol with aims to reduce the greenhouse gas emissions and to shift towards a low carbon economy. The country committed itself to limit the emissions to 34% below the business-as-usual growth trajectory by 2020, and by 42% by 2025. Especially the buildings sector is a priority in South Africa as it is a major user of energy with significant potentials to reduce energy consumption and greenhouse gas emissions. In new buildings, in the commercial sector 40 to 50% and in the residential sector 30 to 40% of energy could be saved. The aim of the regulators is to support buildings that are better insulated, less prone to air leaks and consequently less reliant on electricity for heating and cooling purposes. Appliances are another relevant cause for a large amount of energy consumption. Therefore - with buildings and appliances - the government put a focus on these two important areas with the general goal to achieve a low carbon economy. Programmes with major relevance to achieve this goal are mandatory energy performance standards for buildings and appliances, appliance labelling schemes, demonstration programmes, energy management system promotions as well as awareness raising campaigns.[3]

# 2 Barriers

The term energy efficiency originates as a response to the various challenges encountered through energy use. Energy efficiency can be described as the ability to do more task with less energy.[2] Retrofitting is popularly associated with buildings since the lifespan of building structure and fabric is considerably longer than the installed components. Research has proven [6] that the retrofitting of existing buildings is one of the significant ways of drastically reducing greenhouse gases emissions and energy consumption on a global scale. From the various definitions by different literature, it can be inferred that building retrofitting is the addition and utilisation of new technologies and features to buildings to enhance their effectiveness and efficiency. Buildings require a significant retrofitting at least once in their lifetime to prevent deterioration to the point at which they become uninhabitable. On the other hand, a rule of thumb is that buildings require refurbishment (medium level) every 50-60 years and a major one every 120 years.[2]

A large amount of energy is consumed by most buildings (specifically educational, since the energy usage is focused on thermal comfort and is very dependent on HVAC system) in hot, arid climates. The processes leading to the production, generation and distribution of energy is identified as having a negative environmental impact on the ecosystem and human life. Also, most of the existing buildings are constructed at a time when effectual energy efficiency components are lacking within the relevant building codes. Retrofitting has, therefore, become one of the ways of addressing the issue of energy consumption in buildings. Although energy is not the main reason for building retrofitting, full consideration should, however, be given to the renewal and efficiency of energy systems in any retrofitting project. Other objectives of building retrofitting include redefining the floor layout, counteracting a poor state of repair, increasing indoor comfort conditions and reducing energy use.[2]

## 2.1 Positives and Negatives of Building Retrofitting for Energy Efficiency

### 2.1.1 Negatives Aspects

Construction professionals and other relevant stakeholders are faced with numerous challenges as procuring required materials and components, and high initial cost involved; challenges of regulating and improving energy efficiency in existing buildings as compared to new constructions.

The retrofitting materials for enhanced blast performance of structures described in [7], frequently involves high initial costs in retrofitting projects. Various retrofitting schemes are used such as: Aluminium foam, Fiber reinforced polymers, Polyurea, SHCC/ECC (Strain Hardening Cementitious Composites/ Engineered Cementitious Composites) and Steel jacketing. They will be better described in section 4 of this report.

In new buildings, it is much easier to employ energy efficiency components and technologies rather than incorporating such through retrofitting. Non-existent or incomplete building specific information is listed as another significant challenge. Difficulty in enforcement and monitoring of compliance with energy codes during retrofits, little or no incentives for building owners to invest in higher energy efficiency than required norms, and absence of regulatory power to mandate improvements in building performance are challenges/barriers to a building retrofitting project for energy efficiency. Others are reluctance or failure of building managers/owners to voluntarily submit energy consumption data, low attractiveness of government-mediated financing with private institutions, uncertainty over continued participation of building occupants over the consecutive years, low attractiveness of short-term financial incentives for retrofitting, and absence of innovative measures to overcome industry resistance.[2]

### 2.1.2 Positives Aspects

Regardless of the challenges of building retrofitting for energy efficiency, the benefits are significant and cannot be over-emphasised. Improved material resources efficiency, improved energy efficiency, minimised energy and material losses, reduced environmental impacts, cost savings, increased production rate, and optimisation of building components performance are benefits of retrofitting. From Table 1, It classified the benefits of building retrofitting for energy efficiency into three groups namely; social benefits, market benefits, and environmental benefits. The benefits of building retrofitting for energy efficiency when compared to the challenges are enormous and imperative in meeting the sustainability objective of the construction industry.[2]

| Social | Market | Environmental |
|---|---|---|
| Provides baseline and annual energy consumption which allows building managers/owners to monitor improvement measures | Job creation through increased demand for energy engineers and auditors | Rapid reduction in energy usage |
| Provides transparent building energy efficiency for prospective tenants/buyers and the public | Saves energy expenditures following improved building management or retrofitting | Reduces greenhouse gas emissions |
| Provides information to building owners on potential retrofitting actions, costs and payback periods | Increases the growth of green building and energy efficiency certifications such as Energy Star | Reduces energy consumption |
| Enhance capacity to improve environmental performance | Creation of carbon market | Assured conformity of newly installed building systems to specific energy efficiency norms |
| Secures smaller building participation | Stimulates retrofitting activities | Rapid reduction in water usage |
| Fosters tenant and owner relations and sustainable office practices | Saves operational expenditures arising from high building system components | Encourages the use of renewable energy |
| Users/occupants involvement through a holistic approach to building sustainability | Increases the uptake of energy efficient retrofitting technologies and building system components | Assured operation of building systems at most energy efficient level |

*Table 1 - Classification of the benefits of building retrofitting[2]*

Since the building sector alone contributes 40% of total energy consumption and one-third of greenhouse gases globally, the sector represents the best avenue with a vast potential for reducing harmful emissions and energy usage. It is based on the afore-mentioned that this paper assesses the barriers to retrofitting buildings for efficient use of energy in South Africa.[2]

The result in Table 2 presents the agreement level of respondents on the barriers to building retrofitting for energy efficiency in South Africa. At first sight we see that low income of building owners/occupants are predominant. The study identifies the barriers to building retrofitting for energy efficiency in the Gauteng province of South Africa. [2]
We identify problems in order to be solved, therefore in the following pages of this report some of the solutions will be shown on tables and discussed.

| Barriers | Mean | Standard Deviation | Rank |
|---|---|---|---|
| Low income | 4.16 | 0.842 | 1 |
| High investment cost | 4.14 | 0.756 | 2 |
| Occupants resistance | 3.98 | 0.845 | 3 |
| Low consumer appeal | 3.96 | 0.807 | 4 |
| High upfront costs | 3.96 | 0.605 | 5 |
| Lack of municipal support | 3.82 | 0.873 | 6 |
| Misconception on retrofitting technologies | 3.80 | 0.904 | 7 |
| Occupant's disruption | 3.80 | 0.857 | 8 |
| Building orientation | 3.72 | 1.089 | 9 |
| Immature market | 3.68 | 0.794 | 10 |
| Lack of education | 3.62 | 0.878 | 11 |
| Lack of knowledge | 3.60 | 0.857 | 12 |
| Capital risk | 3.58 | 0.810 | 13 |
| Poor quality installation | 3.58 | 0.883 | 14 |
| Lack of technical expertise | 3.50 | 0.909 | 15 |
| Lack of cost-effective components | 3.34 | 0.872 | 16 |
| Building owner's lifestyle choices | 3.26 | 1.026 | 17 |
| Lack of capacity | 3.26 | 0.922 | 18 |
| Lack of information | 3.22 | 1.016 | 19 |
| Lack of incentive for investors | 3.22 | 0.887 | 20 |
| Lack of personal incentive | 3.18 | 0.962 | 21 |
| Lack of energy professionals | 3.16 | 0.934 | 22 |
| Lack of monitoring | 3.04 | 0.755 | 23 |
| Status quo | 3.02 | 1.020 | 24 |
| Lack of energy efficient materials and components | 3.02 | 0.869 | 25 |

*Table 2 - Barriers of building retrofitting for energy efficiency[2]*

As of 2010, the built-up area of South Africa was estimated to be around 1,164 million m$^2$, with around 75% being residential. From 2000 to 2012 the number of residential buildings in South Africa had increased by 42% from 10.3 million to 14.6 million. As of 2015, the residential sector was estimated to consist of ca. 16 million homes. This is expected to grow to between 19-20 million by 2030. Of these 1 in 4 households, or around 3.3 million households, live in informal dwellings (2009). There is a general short of affordable housing in South Africa. In addressing this the South Africa government, between 1994 and 2009, provided subsidies for 2.8 million low income households. It continues to address this and has aimed to construct 1.5 million houses, for lower- and middle-income groups by 2019, as part of the Human Settlements Vision 2030. The average size of a South Africa household declined from 3.9 in 2001 to 3.6 in 2007.[5]

| Buildings Completed | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Affordable housing < 80m$^2$ | 902955 | 808514 | 764268 | 791987 |
| Dwelling houses > 80m$^2$ | 2805442 | 2859082 | 2776600 | 3158391 |
| Flats & townhouses | 1104767 | 1218234 | 1166426 | 1174581 |
| Other residential | 45645 | 88659 | 88528 | 73155 |
| Additions & alterations: residential | 1466959 | 1722368 | 1120747 | 1160198 |
| Non-residential: Offices | 462586 | 795560 | 609266 | 604604 |
| Non-residential: Shopping | 499159 | 565853 | 572864 | 545840 |
| Non-residential: Industrial | 1128375 | 955483 | 1124811 | 994020 |
| Non-residential: Other | 200640 | 229563 | 213235 | 183576 |
| Additions & alterations: Other bldgs. | 549710 | 665363 | 496990 | 431189 |
| Total | 9166238 | 9908679 | 8933735 | 9117541 |

*Table 3- Private Sector: Number of m2 erected*

The total Energy Consumption in the building Sector from 2012 (the most recent year for which aggregate data is available) shows a final energy consumption of: Industry 35%, Transport 29%, Agriculture 2%, Commerce and Public Services 7%, Residential 25%, Non-specified (other) 2%.

Due to the mild climate, the need for heating and cooling in South Africa is relatively low with cooling demand and heating demand for example being responsible for less than 5% and 7% respectively of the total energy consumption in the building sector. However, the residential sector consumes about 17.5% of the total electricity generated, with their demand at peak periods amounting to over 30%. This has also been steadily increasing with a 45% increase in the years from 1990 to 2010. [5]

# 3 Energy Efficiency Strategy

**Key Facts**

- Commercial and Public Buildings account for 6.7% of final energy demand. The Commercial sector alone contributes 45% towards total national GDP;
- The majority of energy is used in the form of electricity, the main end-uses being HVAC systems, lighting and office equipment;
- The Commercial sector is undergoing significant growth which presents the opportunity to capture energy efficiency at the design stage of new stock.

**Core Objectives**

- To demonstrate the Government's commitment to sustainable energy development within its own building stock;
- To progressively upgrade the energy performance of existing public and commercial building stock;
- To achieve best practice energy performance in new public and commercial building stock.

**Approach**

- The Government will lead by example through raising energy efficiency awareness and by implementing specific measures within its own estate;
- Energy efficiency standards for buildings has been completed called the SANS 204 standard and must now be made mandatory by making it part of the National Building Regulations of the dti, together with a building Energy Audit programme;
- Emphasis will be placed on incorporating energy efficiency into building design and energy efficient technologies will be introduced in existing buildings;
- Energy management systems for buildings will be tested, demonstrated and promoted as well as the Green Building rating system and modelling tool from the Green Buildings Council of South Africa;
- In conjunction with the implementation of SANS 204, energy labels will be developed to assist with compliance rating.

In 2008 a programme was given by the National Energy Efficiency Strategy of the RSA, which all construction and reconstruction must follow. Table 4, Table 5, Table, 6, Table 7.

*Table 4 - Commercial and Public Buildings Sector Programme [4]*

The implementation of Energy Labels will bring a better control and fast execution of the new strategic plan. Commercial and public buildings being erected where people gather in greater number than other places (residential, private buildings) and spend more time during the day. A special look in HVAC system would be a key to significantly reduce the energy consumption, not disregarding the fact of maintaining or improving the inside thermal comfort.

| Output Activity | Measures | Timeframe | Responsibilities |
|---|---|---|---|
| Energy Efficiency Standards for Commercial and Public Buildings | • Develop Energy Efficiency Standard for Office Buildings (SANS 204) | Completed | |
| | • Incorporate SANS 204 in National Building Regulations | Phase 2 | DME, the dti, SABS, CSIR, Architects, Building Industry |
| | • Energy Labels (Compliance Green Buildings Council) | Commenced | |
| | • Implementation of standards | | |
| | • Development of labelling according to use categories | | |
| | • Standard for existing buildings required | Phase 3 | |
| | • Certification wit energy efficiency standards | | |
| | • Develop a Green Buildings Manual. | Phase 3 | |
| Mandatory Energy Audits for Commercial Buildings | • Introduce compulsory building auditing | Phase 1 | DME, Training Certification Authorities – ECSA, Public Works |
| | • Prepare Audit Standard and framework | | |
| | • Prepare monitoring and evaluation protocol | Phase 2 | |
| | • Identify/train/certify both trainer and trainee auditors (BEE) | | DME |
| | • Determine/clarify financing mechanisms | | Treasury/DPW/DME |
| | • Address problem of import duties on equipment | Phase 3 | DME |
| | • Monitor quality of audits as well as effect on overall consumption | | DME |
| Energy Management Systems | • Test and showcase energy management systems | Phase 1 | SABS, Manufacturers, DME, DPW, Building Industry |
| | • Promote energy management systems | | |
| | • Ensure triple bottom line reporting | | |
| Technologies | • Efficient Lights Programme | Phase 1 | DPW, DME |
| Thermal Measures (HVAC) | • Monitor Programme | Phase 2 | DPW, DME |

*Table 5 - Commercial and Public Buildings Sector Programme [4]*

| |
|---|
| **Key Facts**<br>• The Residential Sector accounts for 17,9% (2004) of final energy demand;<br>• Much of this energy is consumed in the form of biomass in the rural areas, but an increasing amount of electricity is used in middle and high income homes and as the national electrification programme reaches more users<br>• Savings can be anticipated in thermal energy demand from the incorporation of energy efficiency measures (thermal insulation) in new housing, the subsidisation of solar water heaters, from the implementation of appliance labelling and standards and through massive education and awareness campaigns |
| **Core Objectives**<br>• To combat pollution on health grounds;<br>• To enforce standards for housing and labelling/efficiency standards for household appliances;<br>• To introduce state-of-the-art technologies. |
| **Approach**<br>• Awareness raising to communicate the cost-benefits of energy efficiency in the home;<br>• Introduction of appliance labelling;<br>• Demonstration projects to create an incentive to invest in energy efficiency;<br>• The approach will initially address higher income (i.e. higher usage) homes and state-subsidised housing incorporating energy efficiency measures as a standard feature<br>• The standard for energy efficient housing (SANS 204) to be made mandatory by its incorporation into the National Building Regulations. |

*Table 6- Residential Sector Programme[4]*

A long-term change programme, considering the fact that those changes does not rely only on the government/institutions but also on the house owners' behaviour towards this new Energy Efficiency Strategy plan.

Many aspects should be taken in consideration, one of them is on the budget of each resident. A better look on the recycle process and renewable sources such as solar panels, biomass, etc. The old or not recommended materials from those dwellings could be recycled by larger or small institutions. House owners' should be compensated, to cover the expenses done during this process. It will also motivate and speed up the new changes, from the house owners' side.

| Output/Activity | Measures | Timeframe | Responsibilities |
|---|---|---|---|
| Standard for Housing | • SANS 204 for energy efficient housing<br>• Incorporate SANS 204 in National Building Regulations<br>• Monitoring and dissemination of results | Completed<br><br>Phase 2 | The dti, EE Experts, CSIR, Building Industry, Thermal Insulation Industry,<br><br>DME |
| Appliance labelling | • Establish standards for household appliances<br>• Label household appliances<br>• Make the Label mandatory<br>• Market appliances with labels<br>• Monitor progress | Phase 1<br><br>ongoing | DME, SABS, Eskom, Appliance Manufacturers, retailers, servicing industry<br>GEF Funding |
| Awareness Raising Program | • Development of specific program<br>• Implementation | Phase 1<br>ongoing | DME, Eskom DSM, GCIS, DPE |
| Efficient Lighting Program | • Demonstration in all sectors<br>• Implementation<br>• Monitoring | Phase 1<br>Ongoing<br>ongoing | DME, Eskom DSM, Municipalities, DPW |
| Non-electric Appliance Standards | • Study of fossil and biomass-using appliances<br>• Draft standards developed<br>• Standards (mandatory for some appliances)<br>• Implementation | Phase 1<br><br>Phase 2 | DME, Manufacturers, Eskom, SABS<br><br>DME, Manufacturers, Eskom, SABS |
| Fuel Standards | • Studies<br>• Development of standards<br>• Implementation | Phase 1<br><br>Phase 2 | DME, Manufacturers, SABS<br><br>DME, Manufacturers, SABS |

*Table 7- Residential Sector Programme[4]*

# 4 Building Retrofitting for Energy Efficiency

As it was addressed in section 3 some retrofitting schemes [7] are developed to blast retrofitting solutions presenting specific advantages and limitations. Those are:

Aluminium foam - May be suitably employed as an economic sacrificial cladding alternative.

Fiber Reinforced Polymers - Enhancement of the diagonal shear capacity (beneficial for columns); Enhancement of flexural capacity (beneficial for walls & slabs); Effective in checking the generation and spread of debris, light weight & high strength; Significant resistance to corrosion; Relatively easy handling; Non-intrusive; Despite the high initial costs incurred, a life cycle assessment of the associated benefits still makes its use advantageous. Limitations: on applicability in areas characterized by high strain demands (e.g. close- in blasts) that exceeds their strain capacities (due to the high levels of localized deformations); Secondary debris or fragments can lead to fiber rupture; FRP de-bonding and delamination at the FRP- concrete interface can lead to the initiation of a brittle failure; Involves high initial costs

Polyurea - Offers an appreciable level of protection; Effective in arresting and checking the generation of debris.; Characterized by high strain capacities; Can also be effectively applied as a hybrid scheme with other retrofitting materials (e.g. CFRP) to exhibit improved performances. Limitations: Requires spraying equipment for application; The level of protection offered is less than that offered by the FRPs.

SHCC/ECC - SHCC, being cement based composite in nature, is fairly compatible with concrete due to the compatible physical and mechanical properties; Exhibits adequate tensile strain capacities, energy absorption, tensile strength and spalling and scabbing resistance. Limitations: In- situ production (to maintain sufficient sprayability) would require skilled workmanship and extensive supervision; Production would also require extensive testing schemes to ensure that the final product meets the requirements; Procurement of the required materials (e.g. fibers, fine sand) might pose a challenge.

Steel jacketing - Externally bonded steel jackets are effective in enhancing the flexural capacity of beams, walls & slabs; Lateral confinement provided enhances the axial capacity and ductility of columns; For cases characterized by high strain demand (e.g. close- in blast), steel jacketing a better alternative to FRP strengthening. Limitations: May be characterized by the premature failure of welds for close- in type blasts; High associated dead load; Corrosion being another disadvantage; Requires careful maintenance.

In 2010 renewables accounted for 60% of the energy consumption in the residential building sector. This is in part due to the fact that 18% of the buildings are without electricity and rely on biomass for energy. Biomass fuels are used for the cooking and hot water by 60% of households in the lowest income households, which make up 7% of the total number of households. It is estimated that energy efficiency here could reduce energy consumption by 40-60%. It was estimated that the energy savings in the building sector through the solar hot water program saved around 600 GWh of electricity, or about 630 kt $CO_2$ between the years of 2010-2014. Lighting and services are responsible for 60% of the energy consumed in the service sector and 20% in the residential sector. Passive thermal design could bring at least a 5% improvement in the energy consumption.[5]

# 5 Conclusion

In the past the focus in South Africa has been more on green buildings, on a voluntary basis, however the South African Government has a strong interest in energy efficiency in the building sector and has been implementing measures to improve it. South Africa has thus achieved significant progress in improving building energy efficiency, much of which can be attributed to carefully planned development strategies, and strong and consistent support from the government.[5]

# 6 References

## Bibliography

[1] Clean Energy Solutions Center. (2017). Enabling Energy Efficiency in South Africa's Commercial Buildings. https://www.nrel.gov/docs/fy16osti/66294.pdf.

[2] O A Oguntona, B. M. (2019). Barriers to retrofitting buildings for energy efficiency in South Africa. *IOP Conference Series: Materials Science and Engineering*, https://iopscience.iop.org/article/10.1088/1757-899X/640/1/012015.

[3] https://bigee.net/en/country/za/overview/. (2016).

[4] Strategy, R. o. (2008). http://www.energy.gov.za/EEE/Review%20of%20National%20Energy%20Efficiency%20Strategy%202008.pdf.

[5] https://bigee.net/en/country/za/buildings/. (2016).

[6] Ma Z, Cooper P, Daly D and Ledo L. (2012). Existing building retrofits: Methodology and state-of-the-art. *Energy and buildings, 55 889-902*.

[7] Goswami A and Adhikary S. D,. (2019). Retrofitting materials for enhanced blast performance of Structures: Recent advancement and challenges ahead. *Construction and Building Materials, 204 224-243*.

## List of Figures



## List of Tables