Overview

Buildings provide protection from the elements, shelter and comfort. Regardless of the weather the indoor temperature during the day and evening should ideally be in a range between 19 and 25°C that is comfortable for the large majority of people. A comfortable indoor climate can be achieved through building design that is appropriate for the local climate. This is also called ‘passive solar design’. In addition, technologies for lighting, heating, cooling and ventilation are often needed that consume electricity or other forms of energy. These technologies are called ‘active systems’. Energy efficient buildings seek to maximise the effects of passive design and to minimise the use and energy consumption of active systems. If the energy for the active systems is generated from renewable sources the building may become a ‘net-zero energy building’.

Energy Efficiency through Passive Design

The local climate plays the determining role in designing energy efficient buildings. The sun’s movement, the prevailing wind direction, the temperature difference between day and night, and the humidity level are local climate conditions that vary from place to place. South Africa consists of several climate zones. Appropriate passive design measures and the need for active systems vary considerably in the different zones. Nevertheless, the basic principle remains that the sun’s warmth should be harnessed and retained in the colder winter months, and should be minimised during the hot summer months.
Examples of passive solar design are:

- **Orientation**: Depending on orientation rooms are warmer or colder. Well-used spaces should face north with overhangs over their windows. South facing rooms are cooler. East and west facing rooms can get very hot in summer as the low sun shines into windows without protection.

- **Shading**: Roof overhangs or other shading devices on the north side let in the lower winter sun but shade rooms from the higher hot summer sun. East and west facing windows often need vertical protection against the lower sun such as louvres or shutters. In hot climates vertical protection is also useful for north facing windows during equinox periods when the sun in lower in the sky.

- **Landscaping**: Planting evergreen trees or shrubs to block strong winds and deciduous trees to provide shade and reduce sunlight reflection in the summer, but let sun through during winter, help to reduce the need for heating and cooling.
- **Windows**: Window in sensible orientation and size let in light and catch winter sun, but very large windows can prevent the retention of warm or cool air inside when desired. In some circumstances double glazing can help maintain internal temperatures, but it is relatively expensive.

![Figure 4: The low sun warms north facing rooms in winter](source)

- **Ventilation**: Ventilation provides fresh air and cool breezes in summer. Ventilation is critical for health especially in rooms occupied by many people. In naturally ventilated buildings ventilation is achieved by opening windows. In addition air bricks ensure permanent ventilation.

- **Passive Cooling**: Natural ventilation can be enhanced by orienting the building to use the prevailing wind breezes for cooling. This requires inlet openings low to the ground and outlet openings in the opposite wall (cross ventilation). Opens plans maximise cross ventilation. Another method is to rely on ‘the stack effect’ of hot air rising inside and escape through vents in the roof. This also requires low level inlet openings.

- **Lighting**: Natural light through windows and light wells reduces the need for artificial lighting. Artificial lighting is an internal source of heat.

![Figure 5: Cross-ventilation and ‘stack effect’ for ventilation and cooling](source)
Municipal Initiatives

- **Building Materials:** Heavy materials such as concrete floors and brick walls absorb heat from direct sunlight during the day to release it at night, and absorb the coolness during the night to help reduce hot daytime temperatures. This contributes to keeping the building cool during the day and warm at night.

- **Surface Colours:** Light coloured paints and materials on roof and facades reflect unwanted solar radiation in summer (see textbox on Albedo Effect).

- **Insulation:** Insulation of the roof and (in cool climates) of the walls helps to keep the inside temperature warm in winter and cool in summer.

![Figure 6: Combination of passive design measures for thermal comfort](https://www.slideshare.net/swapnika15/passive-coolingtechniques)

**Weather sealing and ventilation**

A significant amount of energy is lost from buildings when the ‘envelope’ of the structure is compromised. Air leakage can result in major energy loss from a building, and ensuring the envelope is continuous and consistent minimizes this loss. Weather sealing is especially important in buildings with HVAC systems that need to work harder if conditioned air escapes through gaps.

Draft through gaps at doors and windows is the most significant concern and can usually be addressed at little cost. However, weather sealing must not prevent sufficient ventilation. Especially in residential buildings with high occupancy such as low income homes, a lack of ventilation often results in dampness and the development of fungus on walls. Fungus is a serious health hazard. In these cases, health should be prioritised and air bricks installed to ensure permanent ventilation.
Many modern and especially commercial buildings have been built without much consideration of passive design and rely strongly on technology such as Heating, Ventilation and Air-Conditioning (HVAC) systems and electric heaters to provide a comfortable indoor climate. Using electricity for these functions is very inefficient and costly. Where active systems are needed, the following interventions can increase their energy efficiency:

- Replacement of electric heaters with gas heaters.
- Installation of efficient HVAC systems and minimal use of the systems only at hot times of day and year (see below for more detail).
- Installation of ceiling fans to increase air flow for comfort at higher temperatures that use far less power than air conditioners.
- Replacement of electric geysers with solar water heaters.
- Retrofitting of energy efficient lighting. It is noted that energy efficient lights produce less heat and thus reduce the need for cooling.

**Implementation**

Municipalities can influence the energy efficiency of buildings in three ways. Firstly, they have the responsibility to assess and approve development applications including adherence to energy efficiency and usage standards. Secondly, they can ensure that municipal buildings are energy efficient. Thirdly they can promote energy efficient buildings in their area of jurisdiction.

1. Development applications and approval. Municipalities are responsible for checking compliance with the NBR when they approve development applications. The standards for energy efficient design and construction and energy usage in buildings are part of NBR. Municipal building plan assessors need to apply the energy efficiency standards outlined above.

2. Municipalities must ensure that low-cost housing constructed in their area of jurisdiction complies with energy efficiency measures such as ceilings that have become standard through the directive of the Minister of Human Settlements of 1 April 2014.

3. Municipalities should strive to increase the energy efficiency of municipal buildings and facilities. This can be done through campaigns educating staff and municipal political leaders on energy efficiency in the workplace. The municipality should establish a policy that allows capital and maintenance budgets to be used for energy efficiency measures. The policy can also set targets for energy efficiency of new municipal buildings or for new buildings to achieve green star ratings. In addition, the EEDSM programme of the DoE provides grant funding for energy efficient municipal buildings. Further funding options for the implementation of energy efficiency measures are performance contracts with ESCO (see case study 5).

4. The municipality should educate building owners and developers on the benefits of energy efficient buildings. This can be done through campaigns and in collaboration with the local building industry. The municipality can also set conditions for sales of municipal land to investors such as that buildings must achieve Green Star ratings.
Policy and Regulations

Buildings are the largest end users of energy globally and account for 40% of the world’s end use of energy. Energy efficient buildings make an important contribution to reduce energy demand and greenhouse gas emissions.

In South Africa the importance of energy efficient buildings has been acknowledged by government. The DoE has published the first draft Post-2015 National Energy Efficiency Strategy. In its vision it promotes energy efficiency as the ‘first fuel’. It contains baseline data for energy consumption in 2015 against which goals and targets for energy efficiency are proposed for different sectors.

The targets are to be achieved through measures like

- Successive tightening of standards;
- Green leases; and
- Utilisation of Energy Service Companies (ESCO).

The Strategy is still a draft for discussion and may change considerably but it clearly indicates that all sectors including municipalities to act on energy efficiency of buildings.

The South African Bureau of Standards (SABS) has published two standards for energy efficiency in buildings that must be adhered to in all new buildings, including low-cost housing, and in major refurbishments of existing buildings. As a private initiative, the Green Building Council South Africa (GBCSA) has been established. The GBCSA promotes green and climate appropriate buildings including higher energy efficiency. Both initiatives have resulted in considerable change in the building profession and industry.

National Building Regulations (NBR) for Energy Usage in Buildings

The NBR for Energy Usage in buildings have been published in 2011. They are based on the standards briefly explained below. These standards constitute a fundamental change to the building industry and practice in South Africa and a learning challenge for all who have to apply them. The construction industry has undertaken major capacity building efforts for building professionals. However, it is likely that capacity gaps persist, especially amongst officials such as building inspectors in smaller municipalities. This manual provides only an overview of the new regulations and does not replace capacity building and training.

Applying the new regulations requires some understanding of building physics because the regulations principally permit two routes of achieving the standards: the Prescriptive route and the

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1. http://www.unep.org/sbcI/AboutSBCI/Background.asp
2. Government Gazette 16 December 2016
Rational Design route. The prescriptive route applies the measures listed in the standards as ‘deemed-to-satisfy’ the requirements. It is the simplest route to compliance. However, for certain buildings the ‘deemed-to-satisfy’ measures cannot be applied, e.g. it may be impossible to design a north facing building on a small plot in a built up area or on a slope. In such situations, the Rational Design route offers greater freedom to achieve the energy efficiency targets. This route involves the modelling of the building and calculating its energy consumption. The Rational Design requires a specialist and is therefore generally more expensive. The sections below only refer to the ‘deemed-to-satisfy’ measures.

**SANS 204: 2011 – Energy Efficiency in Buildings**

The SANS 204 standard specifies passive design and active systems’ requirements for energy efficient buildings. It differentiates between buildings with natural ventilation and artificial ventilation / air conditioning. Efficiency requirements differ according to the climate zone in which the building is located.

**CLIMATE ZONES**

The standard defines six climate zones in South Africa indicated in the map.

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3 Harris (undated) Handbook for the Application of the Amendments to the NBR for Energy Usage
4 SABS, SANS 204:2011 Edition 1
5 It has been acknowledged by the CSIR who has led the development of SANS 204 that the local climates in South Africa are so varied that up to 35 climate zones may be required to appropriately represent them. This is apparent for example in the significantly different climates of East London and Richards Bay who are currently in the same zone. The number of climate zones may be expanded in future updates of the standard.
Table 1: Description of climate zones with major cities

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
<th>Major cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cold interior</td>
<td>Johannesburg, Bloemfontein</td>
</tr>
<tr>
<td>2</td>
<td>Temperate interior</td>
<td>Pretoria, Polokwane</td>
</tr>
<tr>
<td>3</td>
<td>Hot interior</td>
<td>Makhado, Nelspruit</td>
</tr>
<tr>
<td>4</td>
<td>Temperate coastal</td>
<td>Cape Town, Port Elizabeth</td>
</tr>
<tr>
<td>5</td>
<td>Sub-tropical coastal</td>
<td>East London, Durban, Richards Bay</td>
</tr>
<tr>
<td>6</td>
<td>Arid interior</td>
<td>Upington, Kimberley</td>
</tr>
</tbody>
</table>


In these climate zones different energy usage is permitted and different ‘deemed-to-satisfy’ measures apply. The standard specifies maximum monthly and yearly energy consumption for buildings in the different climate zones. Compliance with the maximum permitted energy consumption can be achieved through passive design and energy efficient active systems.

PASSIVE SOLAR DESIGN

Deemed-to-Satisfy measures have been defined for:

- Building orientation: Spaces where people spend most hours of their days must face north. Uninhabited rooms such as bathrooms and storerooms can be used to screen unwanted western sun or to prevent heat loss on south facing facades.

- Sealing of the building envelop to limit air leakage: This is especially relevant for buildings with HVAC systems.

- Energy efficiency of building components such as floors, walls, roof, windows and shading: Building components must achieve thermal resistance values i.e. they must delay the transmission of heat or cold through the component by a certain number of hours. This can be achieved by using appropriate building materials and constructions. The number of hours varies in the different climate zones.

ACTIVE SYSTEMS – BUILDING SERVICES

Buildings require services for lighting, thermal comfort and hot water. The SANS 204 sets limits for their energy consumption. Examples are:

- Building designers are encouraged to maximise the use of natural light. Maximum standards for the energy consumption of lighting are prescribed.

- A minimum of 50% of the water heating requirements must be provided by means other than electric geysers. Alternative means include solar water heaters and heat pumps.

- In buildings with mechanical ventilation, HVAC systems must be designed to most efficient standards and should only supply areas in need of heating or cooling, not the whole building. It is recommended to set the thermostatic controls at 20°C in winter and at 24°C in summer.
The SANS 10400-XA standard is a summary of the SANS 204 and other standards into a single reference for stakeholders to ensure compliance with energy efficiency requirements of the National Building Regulations (NBR). Requirements include:

- The orientation of buildings, with well-used areas facing North to make best use of natural sunlight and warmth;
- Suitable roof overhangs to keep out the high summer sun but let in the winter sun, when the sun is lower in the sky;
- Sensible fenestration (windows) to let in light and sun, but not so much that natural warmth or coolness cannot be retained;
- Use of appropriate heating, ventilation and air-conditioning installations where requires; and
- At least 50% of water heating must be done in an energy efficient way e.g. through a solar water heater or heat pumps.

The SANS 10400-XA is part of the NBR and must be adhered to. Municipalities are responsible for assessing and approving development applications including their adherence to the NBR (see section xx).

**Green Building Council South Africa (GBCSA)**

Green Building Councils exist in many countries. They are non-government and not-for-profit organisations promoting green buildings. In South Africa the GBCSA was established in 2007. “The Green Building Council South Africa leads the transformation of the South African property industry to ensure that buildings are designed, built and operated in an environmentally sustainable way.” The GBCSA does this by

- Raising awareness of the benefits of green building
- Supporting government to lead by example, to legislate and facilitate the adoption of green building practices.
- Recognising and rewarding industry leaders who achieve green building excellence.

The GBCSA has developed Green Star Rating Tools for the following building types

The tools rate green building measures in many categories such as Indoor Environment Quality (IEQ), Energy use, Water use, and embodied energy of Building Materials. For each category credits are given if the building achieves improved environmental performance. The credits are weighted and a percentage score is calculated. If the score is sufficient the building will receive one of the following Green Star Certified Ratings:

- 4 Star Green Star Certified Rating (score 45-59) signifies ‘Best Practice’
- 5 Star Green Star Certified Rating (score 60-74) signifies ‘Australian Excellence’
- 6 Star Green Star Certified Rating (score 75-100) signifies ‘World Leadership’

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6 SABS, SANS 10400-XA: 2011 Edition 1
7 https://www.gbcsa.org.za/about/what-is-green-building/
8 Embodied energy is the energy that was used to produce the building material. For example cement has very high embodied energy and its use should be minimised.
9 The South African green star rating is based on the Australian system.
In the energy category the energy consumption of the building is modelled and compared to the SANS 204 minimum requirements. Credits are awarded for low consumption. In addition, credits are awarded for renewable energy installations.

The GBCSA has been very successful especially in the corporate sector and to some extent in the government sector. Green Star rated buildings have become prestigious attributes for companies and government institutions. To date more than 200 hundred buildings have been certified and rewarded four or more Green Stars.

Retrofits to existing buildings

SANS regulations and the GBCSA rating system only apply to new buildings and to major refurbishments of old buildings but not to the existing building stock that makes up around 95% of all buildings. In order to increase the energy efficiency of these buildings retrofit measures are required. How to retrofit water heating and lighting has been discussed in previous chapters. Below are some examples of retrofit measures to improve the thermal performance of buildings and save energy for heating and cooling.

PASSIVE DESIGN

In existing buildings measures improving the energy efficiency are more limited than in new buildings. However effective retrofit measures include:

- Installation of ceilings and roof insulation. Especially in single story buildings the roof constitutes a large portion of the building envelope. The thermal performance of a roof can be improved through:
  - the installation of aluminium foil insulation directly under the roof sheets; and/or
  - the installation of an insulated ceiling or the placement of insulation on top of an existing ceiling.
- Installation of shading devices such as awnings to north facing windows. In hot climate zones vertical shading devices...
such as shutters and louvres reduce the heat gain of west and east facing windows and of north facing windows at equinox.

- Painting of roofs in light and reflective colours reduces the absorption of heat and results in a cooler interior.

**Cool Surfaces: Cool Roofs (Albedo Effect)**

Dark coloured roofs and other surfaces of buildings get very hot in the sun and transmit heat into the interior. White coloured roofs reflect the solar radiation keeping the interior cooler. This is called the Albedo effect. The term Cool Roof refers to roofs that reflect the radiation from the sun and increase the thermal comfort in buildings. The effect can be achieved or enhanced through reflective paints that are available in different colours.

The South African National Energy Development Institute (SANEDI) has conducted a project on cool surfaces. The project has established a database of approved reflective paint products.

The project focused on low-income housing and found that reflective coating dramatically improves the thermal comfort. The image shows corrugated iron sheets coated with cool paint. Before the coating they were too hot to touch, but after coating the temperature was reduced significantly.

However, the technology is also very valuable in buildings with HVAC. Cool surfaces reduce the cooling load and can cut the electricity used for air conditioning by up to 20% on the top floor.

The image shows a cool roof in Groblersdal, Northern Cape, where the measured cooling effect in the building was between 7 to 10°C. However, SANEDI expects that the cooling effect in moderate climate zones will be between 2 to 4°C.

![Figure 10: Reduced temperature of corrugated metal sheet through reflective paint](Source: https://za.usembassy.gov/renewable-technology-makes-life-better-cooler-ask-khes/)

![Figure 11 – Roof with reflective paint](Source: courtesy of SANEDI http://www.sanedi.org.za/CoolSurface.html)

**ACTIVE SYSTEMS**

HVAC systems are the main consumers of electricity in office and commercial buildings where they require 30% to 60% of the electricity used\(^\text{10}\). There are central HVAC systems, typically supplying large office and commercial buildings, and individual air-conditioning units supplying small buildings, single room or complement poorly performing central HVAC systems. There are many different types of central HVAC systems. The image below shows an all-air system where air is cooled and pumped through ducts and released into the rooms. Other systems use water as cooling medium or a combination of water and air.

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\(^{10}\) van Els (2013) A simple guide to HVAC and lighting efficiency in commercial buildings. This guide provides details on energy efficient HVAC systems including retrofitting existing systems.
HVAC systems should be designed in such a way that the temperature in different parts of a building can be regulated separately and switched off in rooms when they are not used (such as boardrooms). In older central systems this is often not possible. However, technical adjustments, improved management and behaviour changes of the occupants can increase the performance and energy efficiency of HVAC systems significantly. Below are a few measures to improve the energy efficiency of HVAC systems.\textsuperscript{11}

- Using ‘fresh’ air to cool a building down at the start of the day. The outside air, even in summer, is cool early in the morning and by switching the air conditioning system's fans on, the cool air is drawn into the building. Not only does it lower the inside temperature, but it also flushes out the stale air from the previous day. In this way, the building is cool and fresh when the employees arrive, and operating of the energy intensive chillers is reduced.

- Adjustments to the temperature setting of the air conditioning system in line with the recommendations of SANS 10400 XA will result in substantial savings. The recommendation is for set points in winter at 20°C and in summer at 24°C. Each degree adjustment towards the outside temperature results in approximately 7% electricity savings of the HVAC system. A less severe difference between indoor and outdoor temperature is also healthier for the building occupants.

- Towards the end of the working day, the building’s air conditioning system could “wander”. This means allowing the temperature to gradually increase, given that employees are due to leave and will then encounter the temperature outside.

- In buildings that allow for natural ventilation (windows can be opened) the HVAC system can be switched off during months with moderate temperatures. This will require considerable education and campaigning as comfort at the workplace is a sensitive issue and many employees are so used to HVAC that they consider it a necessity at all times of the year.

- HVAC technology has improved greatly over the last years, and systems have become far more efficient. Some new air conditioning systems are 30% more efficient than their older counterparts.

- Heating requirements in South African buildings are relatively small and therefore most often provided by electrical elements in the HVAC system. This is a very inefficient way of heating. A several times more efficient system is a heat pump type HVAC system able to operate in reverse mode.\textsuperscript{12}

\textsuperscript{11} For more detail see: UNHabitat (2014) and van Els (2013).
\textsuperscript{12} Van Els (2013).
Building Management Systems (BMS)

A building management system (BMS), otherwise known as a building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors the building’s mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.¹

BMS are typically installed in large commercial buildings, including Green Buildings where they ensure that systems operate efficiently throughout the life of the building.

Figure 11: Building Management System with multiple components


¹ https://en.wikipedia.org/wiki/Building_management_system
Financial Aspects

A 2016 study by the GBCSA of green star rated buildings in South Africa found that the costs of new green buildings are between 1.1 and 5% higher than the costs of conventional buildings. This indicates that the extra costs of building green are marginal. Green buildings have substantially lower operating costs than conventional buildings of which energy costs are a large component. Therefore the business case for energy efficient buildings is strong.

This is reflected in the trend towards ‘green leases’. A green lease contract combines the rent of space and the operating costs. Higher investment costs will result in higher rents but this is more than compensated by lower operational costs. The costs of renting green buildings are principally lower and more predictable than of conventional buildings as rising costs of services like electricity have less impact. Green features have often additional benefits regarding comfort and health and have become a marketing advantage.

There is a strong case for municipalities to apply green building principles to their own new buildings and to major refurbishments and to promote green building in their area of jurisdiction.

Barriers and opportunities

The retrofitting of existing buildings to increase the energy efficiency is generally more difficult and barriers differ according to the measures. The main barriers to retrofit are high investment costs for some measures and lack of capacity and technical expertise.

Barriers for energy efficient lighting measures are relatively low because typical payback periods are between two to four years.

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Measures to reduce the energy consumption of HVAC range from low-cost measures, such as tuning the system, installing sensors and timers that have often pay back periods of less than a year, to major changes or the replacement of the HVAC system which have multi-year pay-back periods. Such measures also require significant expertise and experience.

Passive measures such as installation of shading devices, ceilings or reflective coating of the roof improve the thermal performance of a building and reduce the energy consumption of the HVAC system. However, the pay-back periods are building specific, e.g. measures to the roof have a much higher effect on energy consumption in single-storey than in multi-storey buildings. Choosing and designing the most effective measures requires significant expertise.

Costs and benefits of thermal energy efficient measures need to be designed and calculated for the specific building. Non-monetary benefits such as improved comfort and health of staff must be taken into account although they are difficult to monetarise.

Municipalities should use all funding opportunities for energy efficiency in public buildings (such as the EEDSM programme) and should train staff responsible for building management and maintenance in energy efficiency. A municipal policy on energy efficiency can provide a platform to raise awareness of politicians and staff and to initiate energy efficiency measures.
Case Study 1: Joe Slovo, Cape Town: Sustainable low-income settlement*

The Joe Slovo project is a national flagship housing project of the Department of Human Settlements (DHS). DANIDA, the Danish development funder, supported several sustainable energy interventions in the settlement, and Sustainable Energy Africa oversaw the implementation of these interventions together with JSA Architects. The Joe Slovo settlement is situated in the suburb of Langa, 10 km east of the Cape Town CBD. The low cost houses in the settlement include the following sustainable design elements:

- Improved thermal performance of buildings through insulated ceilings, roof overhangs and double storey, duplex block design i.e. reducing external wall exposure
- Improved energy services through energy efficient water heating through solar water heaters (150 litre low-pressure evacuated tube systems).

The images show the houses in Joe Slovo and conventional low-cost houses in Delft that were used to compare the impact of the sustainable features.

Solar water heaters

SWH were installed on all houses. A community survey conducted after occupation showed that the SWH were most appreciated measure. Prior to the installation households used an average of 8 kettles per day for water heating. Even on cloudy days in winter the SWHs were found to produce 30 to 40°C warm water.

Energy Efficient lights

The houses were equipped with CFL lights. It is noted that a safe disposal and replacement system is required to sustain this measure as poor residents may replace broken CFLs with cheaper incandescent light bulbs.

Thermal design features

The thermal design was optimised with the help of a computer modelling package. The houses are double storey, and have shared walls reducing their exposure to outside air. Most houses are north facing with roof overhangs.

* This case study draws extensively from: SEA (2014). Joe Slovo, Cape Town: Sustainable low-income settlement densification in well located areas. Unless referenced otherwise, information is sourced from this document.
shading windows on the top floor in summer. The houses have insulated ceiling which has become mandatory for low-cost houses through a directive from DHS in 2014.

The impact of the thermal design interventions was monitored and compared with a settlement of stand-alone RDP-type houses in Delft. It found improved thermal comfort in the Joe Slovo houses, being cooler in summer and warmer in winter than the houses in Delft. The figures below show the monitoring results of indoor and outdoor temperatures for Joe Slovo and Delft in summer (March) and winter (May) months. The indoor temperature in the Joe Slovo houses varies only between 18° and 26°C throughout the year while the indoor temperature in Delft houses varies between 17° and 30°C.

Case Study 2: Green Building, Cape Town

Being a promoter of sustainable energy approaches and practices, the founders of Sustainable Energy Africa wanted to show that a green office building can be built with limited financial resources. They aimed to do this through passive solar design and by reusing resources, recycling waste, reducing energy consumption, using renewable energy sources, locally sourcing materials, and reducing water consumption.

INTERVENTIONS

A number of passive solar design features were used to achieve the energy efficiency of the Green Building, including building orientation, shading of windows, and thermal mass. These dramatically reduced the energy required for heating and cooling. The use of natural light was maximized by optimising window area and avoiding deep office spaces. This has made artificial lighting during the day almost unnecessary. Hot water is generated by a solar water heater on the roof. Solar photovoltaic panels generate electricity that is fed back into the City’s power grid if not consumed on site.

During the construction of the Green Building, recycled materials were used for windows, doors, and timber flooring. Reconstituted bricks containing 92% recycled material were used throughout the building. The materials were locally sourced, minimizing transport to the site.

Water consumption has been reduced by using dual-flush toilet cisterns and low-flow taps and shower heads. Recycled grey water and harvested rainwater take care of the water requirements of the water-wise garden. External paving in the parking lot of the Green Building allows water seepage into the aquifer.
The result of the green interventions is a building that surpasses most energy efficiency targets. An office building is considered efficient if it uses less than 100 kWh/m²/year. The Green Building uses only 30-50 kWh/m²/year, whereas conventional offices use 250-400 kWh/m²/year. The cost of the building was 30% lower than the cost of a conventional building, and the value of the building increased by 32% after two years. Also, it has been consistently fully let since completion, showing that 'green' and 'commercially viable' are entirely compatible objectives.

**AWARDS**

The Green Building received the 2004 Sustainable Building Best Practice Award for noteworthy sustainable buildings in Africa, with a score of 3.9 out of 5 concerning social, economic, and environmental factors. It also received the 2004 Cape Times Caltex Environmental Award for outstanding achievement in environmental conservation.
Case Study 3: Eastgate, Harare, Zimbabwe*

The Eastgate Centre is a shopping centre and office block in central Harare, Zimbabwe. It provides 5,600 m² of retail space, 26,000 m² of office space and parking for 450 cars. It was probably the first building in the world to use natural ventilation and cooling to this level of sophistication.

The building form is two nine-storey parallel 146 m ×16 m plan blocks, linked by a 16.8 m wide glass-roofed atrium, with its long axis oriented east-west. The upper seven storeys of office accommodation have double slab floors to enable overnight cooling by outside air. The two lower storeys and the two basement car parking levels have conventional mechanical supply and extract ventilation; the former can be equipped with mechanical cooling if required by their retail tenants.

The building was modelled on the way that termites construct their nest to ventilate, cool and heat it entirely through natural means. The local climate – similar to the South African Highveld – with warm days and cool nights, is ideal for natural ventilation combined with night cooling. The other key factor (an economic one in this case) against the use of a conventional HVAC system was the high cost of importing such plant, the potential lack of skilled labour to service and maintain it, the cost of running it in energy terms, and the frequent power cuts.

Appropriate building orientation, extensive shading and glazing restricted to 25% of the façade were used to keep external heat gains to a minimum, while great efforts were made to limit internal heat gains.

According to computer simulations, the natural stack effect was not sufficient to cool down the building so simple, low power, locally made fans are used to ensure that all floors receive the same quantities of cooling, fresh air.

The energy concept is based on the termite mound analogy: the building mass is used as insulation and the diurnal temperature swings outside keeps its interior uniformly cool. The architects and engineers devised an air-change schedule that is significantly more efficient than in other climate-controlled buildings in the area. Fans suck fresh air from the atrium, blow it upstairs through hollow spaces under the floors and from there into each office. As it rises and warms, it is drawn out through 48 round brick funnels. During cool summer nights, big fans send air through the building seven times an hour to chill the hollow floors. By day, smaller fans blow two changes of air an hour through the building. As a result, the air is fresh, much more so than that from an

* This case study draws extensively from UNHabitat (2014). Unless referenced otherwise, information is sourced from this document.
The air conditioner which recycles 30 percent of the air that passes through it. The distribution system incorporates small-capacity (250–500 W) electric heaters in the supply grilles. The exhaust air is finally extracted into vertical stacks, which in turn lead to the chimneys visible on the roof.

Eastgate’s ventilation system has cost one-tenth that of a comparable HVAC system and uses 35 percent less energy compared to conventional buildings in Harare. The peak temperature in the offices is some 3°C less than it is outside.

Case Study 4: Hotel Verde, Cape Town*

The Hotel Verde has received 6 stars, the highest rating by the Green Building Council South Africa (see section xx Energy Efficient Buildings) for Existing Building Performance it is also LEED (Leadership in Energy and Environmental Design by the US Green Building Council) Platinum certified for both Design & Construction as well as Existing Building: Operation & Maintenance.

Its energy efficient features include:

- 220 Photovoltaic panels,
- Three wind turbines (vertical axis),
- Regenerative drive elevators,
- Energy efficient lighting system with LED lights and occupational and daylight sensors,
- Energy-saving heating and cooling system coupled to ground source heat pumps,

* All information fro this case study provided by André Harms, director and principal sustainability manager at Evolution Consulting (January 2017) www.hotelverde.com
Intelligent Building Management System (BMS),
Many passive design strategies such as double glazing and PV panels as shading devices of windows; and
Energy generating gym equipment.

The innovative HVAC system achieves extraordinary efficiency through a geothermal loop field coupled to ground source heat pumps for central heating/cooling and domestic water heating. The geothermal field consists of 100 boreholes, each approximately 65m deep. Each hole contains a U-bend pipe. Combined, there is approximately 13 km of piping beneath the footprint of the building. Water passes through these pipes to either dump heat (in summer) or gain heat (in winter) from the constant ground temperature at this depth of around 19.4°C, thus using the earth as a huge thermal battery.
This system is well suited for a hotel project in the Cape Town climate as the heating and cooling loads are reasonably balanced over an entire annual cycle and the ambient-, heating-/cooling- and ground-temperatures are such that one can extract energy out of the ground in winter and reject energy into the ground in summer.

The hotel has about 12000 m² usable surface area and the plant has a capacity of 304kW in cooling, 364kW of heating only or 182kW for heating plus 167kW for hot water generation.

At the time of construction (2013) the costs of the system were approximately:

- Geothermal installation (incl. extra earthworks, P&G, fees etc.): R6m
- Plantroom: R9m – R10m (incl. equipment, logistics, installation, delayed commissioning, variation orders, fees etc.)

The system saves around 50% of the electrical energy a conventional HVAC system would require. The expected payback period is 5 to 7 years.

In addition to the technical features education and awareness raising measures are in place. An internal sustainability TV channel displays figures of the BMS illustrating resource consumption and savings to the hotel guests. Signs encourage the use of stairs whilst the gym’s signature concept “What the Watt” engages the guests: the gym machines feed into the electricity grid and the user experiences how hard it is to generate electricity versus how easy it is to squander it.

All information from this case study provided by André Harms, director and principal sustainability manager at Evolution Consulting, January 2017.

www.hotelverde.com
Case Study 5: Performance Contracts for Energy Efficiency Measures

Energy performance contracts refer to the practice of contracting with energy service company (ESCO) to guarantee that the full costs of energy efficiency interventions will be paid back through the energy savings resulting from the interventions. For performance contracts to work, the savings during the contract period must be greater or equal to the investment costs.

There are two types of performance contracts:

**Guaranteed saving contracts**

In the case of a Guaranteed Saving Contract the municipality pays for the energy efficiency measures and the ESCO implements them and provides the municipality with a financial guarantee that projected savings will be achieved for a number of years. If the savings are not achieved the ESCO will reimburse the difference to the municipality. The advantage of this type of contract is that the municipality has financial certainty that it will get its investment back over a specified period of time. A disadvantage is that procuring performance contracts through the municipal supply chain management system is difficult. However, the City of Cape Town has resolved these difficulties and has documented their experience with Guaranteed Savings Contracts.¹⁴

**Shared saving contracts**

In the case of a Shared Savings Contract the ESCO finances the energy efficiency measures through loans and the municipality pays for them through the savings that the measures achieve. The advantage of these contracts is that the municipality does not have a capital expense. The disadvantage of these contracts is that the interest on the loans increases the costs and the pay-back period. Therefore the contract period is likely to exceed three years, which requires a more complex procurement process by the municipality such as applying the process outlines in Section 33 of the MFMA. Also, maintenance of installed equipment during the contract period, adds to the contractual complexity. Very limited and not always positive experiences exist in municipalities with this type of contracts.

The South African Cities Network has set up a website (http://www.energycontractsupport.org/) where the concepts of contracting with ESCOs are explained in a step by step approach.

Further information on ESCOs can be found on the website: www.escos.co.za. This website makes reference to several cases studies in the private and public sector including Guaranteed Performance Contracting by the City of Cape Town.

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¹⁴ SALGA (undated) Energy Performance Contracting – experiences from the City of Cape Town
Support organisations

**CSIR**
Technical support
CSIR can offer support in the areas of research and technology (including testing), training and capacity building. Cities can engage with them as necessary.
www.csir.co.za

**Department of Energy (DoE)**
Capacity building, policy development, funding
www.dme.gov.za

**Development Bank of Southern Africa (DBSA)**
Debt Financing and a limited Technical Assistance grant facility.
www.dbsa.org