GETTING TO ZERO

A GUIDE TO DEVELOPING NET ZERO CARBON BUILDINGS IN SOUTH AFRICA

2020

Acknowledgements

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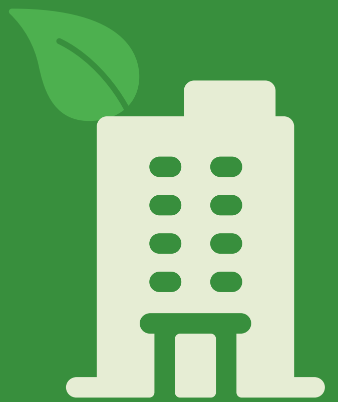
DEVELOPING A NET ZERO ENERGY BUILDING



Net Zero carbon: a highly energy-efficient building, with the remaining energy requirement generated from renewable energy, preferably on-site or off-site if necessary. There should be zero net carbon emissions on a yearly basis.

1. AIM HIGH

Commit to the end-goal. Hire the right team from concept to collaboratively design your building.

Include:

- Designers with low-energy experience
- Building simulations experts
- Tenant and facilities rep's
- Commissioning professionals

2. SET THE TARGET

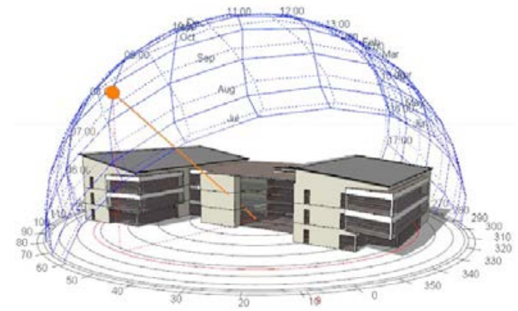
> Lower the energy consumption of the building as much as possible. Set an energy target as a team and stick to it!

RECOMMENDED OFFICE ENERGY CONSUMPTION TO AIM FOR:

50-70 kWh/m²/yr

> Use passive design to achieve 'Comfort Without Aircon'

- Reduce air conditioning loads as far as possible with passive measures.
- Research shows that buildings in most South African cities can operate comfortably without air-conditioning for the majority of the year, if good passive design is incorporated.
- Use simulation tools to maximise efficiencies.



> When choosing active building systems, choose the most efficient options

HEATING, COOLING, VENT

10-30 kWh/m²/yr

Total Office HVAC

LIGHTING AND EQUIPMENT

10 kWh/m²/yr

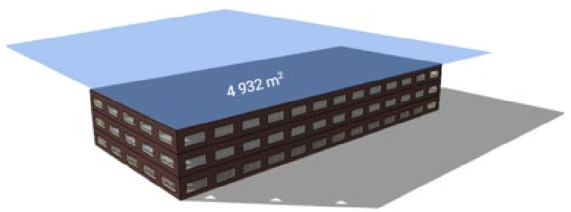
Office Lighting

3. ADD RENEWABLES

Generate as much renewable energy on-site as possible. Purchase off-site if needed. The building should generate as much renewable energy as it consumes overall over the period of a year.

STANDARD ENERGY EFFICIENCY

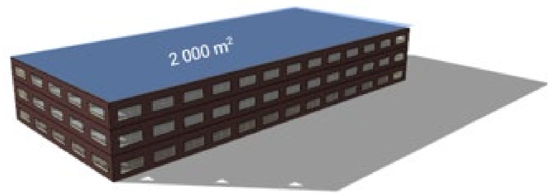
Solar PV area needed to offset building's energy consumption



Building consumes 200 kWh/m²/year (SANS 10400:XA 2011 compliance)

OPTIMISED ENERGY EFFICIENCY

Solar PV area needed to offset building's energy consumption



Building consumes 81 kWh/m²/year

ONCE YOU HAVE SUCCESSFULLY ACHIEVED A NET ZERO CARBON BUILDING, SHARE YOUR SUCCESS WITH OTHERS

Get a Net Zero Certification from the Green Building Council South Africa

This demonstrates to all that net zero carbon buildings are feasible. It's an objective assessment of the project that provides credibility and helps to inspire and educate other project teams who may be considering embarking on the net zero journey.

By committing to developing a net zero carbon building, you are helping to reach a bigger, ambitious goal. Johannesburg, Tshwane, Cape Town and eThekwini are C40 cities that have committed to ensuring new buildings operate at net zero carbon by 2030 and all buildings by 2050.

ALL NEW BUILDINGS NET ZERO CARBON BY 2030

ALL EXISTING BUILDINGS NET ZERO CARBON BY 2050

C40 CITIES | GREEN BUILDING COUNCIL SOUTH AFRICA | ASHRAE South Africa Chapter | SEA SUSTAINABLE ENERGY AFRICA

SECTION 1

INTRODUCTION

Our reliance on fossil fuels to power our buildings and cities is damaging the health of our people and our environment. There is a better way.

Highly energy-efficient buildings can generate the power they need to keep occupants comfortable and productive, on-site and from renewable sources. Known as net zero carbon buildings, they are viable today and crucial for the future.

The purpose of this guide is to show it is possible and offer guidance on how to achieve it.

The main aim is to drive the energy consumption of a building as low as possible. This is done by addressing the main consumers of energy - in a commercial building this is usually heating and cooling, followed by lighting and equipment. The resources spent on keeping people thermally comfortable in a building are substantial, and design teams must keep this in mind from the start. In a residential building, the main energy requirement is usually for water heating.

Using passive design strategies that work closely with the prevailing climate and context, helps to create comfortable buildings for people that are energy efficient. In South Africa, it has been shown that in many areas, well-designed buildings can operate without mechanical heating, ventilation and cooling for most of the year. Building performance simulations make it easier than ever today to understand and predict the way a building will operate, allowing us to intervene and ultimately design and construct the best spaces possible.

Once simulations and cost-effective passive design interventions have driven energy consumption from heating, ventilation and cooling (HVAC) and lighting as low as possible, advances in technology can be used to ensure that the active equipment required in the building is as energy efficient as possible. This guideline provides some useful efficiency targets to aim for.

Once the building's energy requirement is as low as possible, meeting these energy needs with renewable energy can often be achieved on-site, thanks to immense improvements in renewable energy technology today. If not (for example in buildings with limited roof-space in relation to floor area), then off-site renewable energy can be explored.

> Technically, it is absolutely possible to achieve net zero carbon buildings. It requires determination and enabling building standards, bylaws and policies to make it happen at scale. Critical mass of net zero carbon buildings is required to meet political and planetary climate goals. The building sector has the potential for significant greenhouse gas emissions reduction at a lower cost than other sectors.

ABOUT THIS GUIDELINE

This guide is an overview of the concept of net zero carbon buildings in South Africa, and gives guidance and references to approaching a net zero project. The focus is on new and existing commercial buildings, mainly offices, with some reference to the residential sector.

It has been produced as a collaboration between:

- ASHRAE South African Chapter; (American Society of Heating, Refrigerating and Air-Conditioning Engineers);
- C40 Cities Climate Leadership Group (C40) South Africa Buildings Programme;
- The Green Building Council South Africa (GBCSA).

While some technical design information is referenced in this guide, those wishing to explore in-depth design strategies are referred to other resources and documents within the guide (see 'Further reading' p.43). In particular, this guideline references ASHRAE's *Achieving Zero Energy - Advanced Energy Design Guide for Small to Medium Office Buildings*.

ASHRAE South African chapter

The ASHRAE SA chapter, chartered in July 2018, is a volunteer based society of dedicated professionals in the built environment, striving to improve and share building sciences and related industries.

Started in 1894, ASHRAE consists of about 56 000 members internationally, with 132 nations divided into 15 regions, with local chapters supporting each region. These enthusiastic volunteers are in constant communication, sharing their knowledge and experience.

The ASHRAE SA chapter has established two committees (sustainability and simulations) focused on engaging and supporting ASHRAE SA members on the topic of sustainability issues. Through their activities such as the development of this guide, these committees aim to help develop cleaner, safer buildings in South Africa.

The C40 South Africa Buildings Programme (SABP)

C40 Cities connects 96 of the world's greatest cities to take bold climate action, leading the way towards a healthier and more sustainable future. Representing 700+ million citizens and one quarter of the global economy, mayors of the C40 cities are committed to delivering on the most ambitious goals of the Paris Agreement at the local level, as well as to cleaning the air we breathe.

Johannesburg, Tshwane, Cape Town and eThekwini are C40 cities and signed the Net Zero Carbon Buildings Declaration in 2018 alongside other global cities leading on tackling emissions from buildings. Twenty eight cities globally have now committed to regulations and/or planning policy to ensure new buildings operate at net zero carbon by 2030 and all buildings by 2050. Meeting these commitments will require a step change in building energy efficiency policies and regulations in most cities, and in the South African cities technical assistance is being provided to help achieve this accelerated pathway to net zero carbon buildings.

Made possible by funding from the Children's Investment Fund Foundation, the C40 programme is delivered in partnership with Sustainable Energy Africa (SEA), based in South Africa. It includes embedded expert advisors working in each city, to develop net zero carbon building policies and bylaws as part of a roadmap to achieve net zero carbon new buildings by 2030. Their work is supported by additional technical expertise from SEA and other organisations in South Africa, supporting policy development, capacity building and knowledge sharing activities.

This work is aligned to the country's international and national climate change commitments, complementing existing policies, strategies and frameworks.

The Green Building Council South Africa (GBCSA)

The GBCSA promotes sustainable development and property industry transformation through green building programmes, technologies and design practices. The GBCSA has developed comprehensive environmental rating systems for buildings, including Green Star SA, Energy Water Performance and Net Zero / Net Positive.

The GBCSA Net Zero or Net Positive certification recognises projects which take the initiative to completely neutralise (or positively redress) their carbon emissions; water consumption; solid waste to landfill and their negative ecological impacts. The GBCSA certification goes beyond carbon for South Africa, to also include water, waste and ecology, as these are critical stress points in the country.

The GBCSA's Net Zero Carbon rating tool sets out standards for modelling or measuring a building's energy consumption to achieve certification. Project teams document their calculations and submit this to the GBCSA. These submissions are assessed by third parties before issuing a certificate.

The rating tool currently offers two levels of certification:

- **Level 1 :** Building emissions (excluding tenant loads)
  This rating is available for new buildings at Design or As Built stages.
- **Level 2 :** Base building emissions + building occupant emissions
  This rating is available either to new buildings via modelled calculations, or to operational buildings through actual energy measurement.

What is a net zero carbon (NZC) building?

The GBCSA defines a net zero carbon building as "a building that is highly energy-efficient, with the remaining energy requirement generated from renewable energy, preferably on-site or off-site where absolutely necessary". There should be zero net carbon emissions on an annual basis (net zero).

If the energy from renewable sources results in more energy being produced than what is used on site, this is net positive.

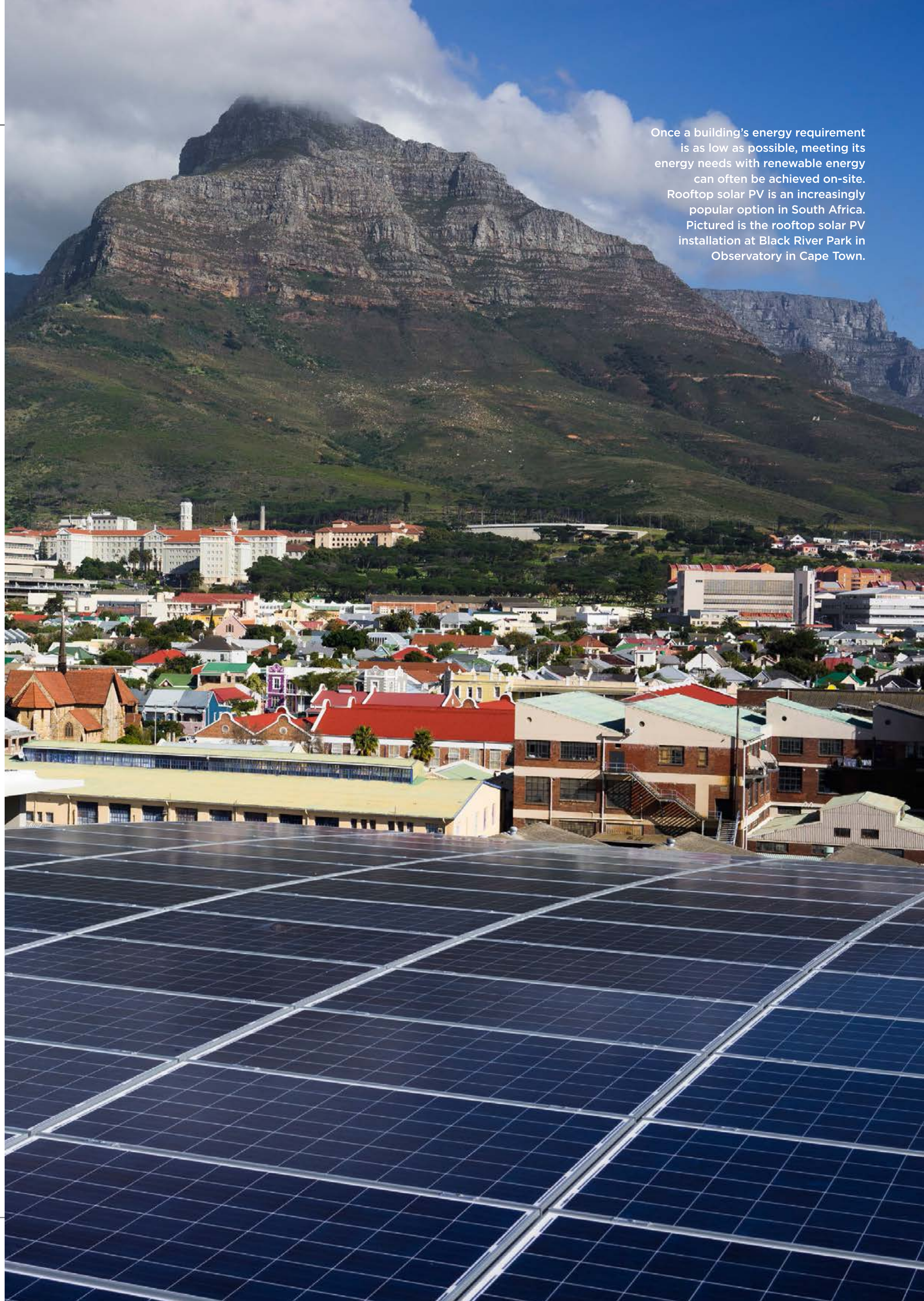
The GBCSA further states that "it is important to note that net zero or net positive does not mean off-grid in terms of energy and water. The grid is a very important component of allowing transfer of excess energy or water from one site to another site where a shortage is experienced. The grid will become more and more important for South Africa to work towards a regenerative society that is able to shift resources from places of excess to places of need – this cannot be achieved by requiring every site to go off grid."

The built environment currently produces one third of the world's carbon dioxide emissions. This sector must drastically reduce the amount of CO_2 it generates.

The motivation for net zero carbon buildings is driven by South Africa's national and local climate change commitments, including the C40 Global Net Zero Carbon Buildings Declaration. South Africa's National Climate Change Response: White Paper issued by the Department of Environmental Affairs in 2012 also outlines the need for an 'optimal mix' of mitigation strategies. It specifically identifies the regulation of commercial and residential building standards to enforce green construction practices in section 8.4.

The White Paper highlights improved energy as an important mitigation strategy. This ideal is reflected across other national policy documents, such as the National Development Plan and the Department of Energy's Draft Energy Efficiency Strategy, which aims for energy use intensity improvements of 20% by 2025 and 37% by 2030, off a 2015 baseline. Tightening relevant building regulations will be required to achieve this mandate.

The knowledge and technology required for zero carbon emission buildings exist, and are explored in this guide. Net zero carbon is possible and imperative, and with determination and enabling policies and legislation, can be implemented far and wide.



Once a building's energy requirement is as low as possible, meeting its energy needs with renewable energy can often be achieved on-site. Rooftop solar PV is an increasingly popular option in South Africa. Pictured is the rooftop solar PV installation at Black River Park in Observatory in Cape Town.

SUCCESS FACTORS FOR DELIVERING NZC BUILDINGS

When embarking on a net zero carbon building project there are important actions that contribute to success. ASHRAE's *Achieving Net Zero Energy* guide lays out important success factors for a NZC building project. Some of these are shared below, with supplementary factors covering aspects of a building project.

1. Develop the culture and mindset

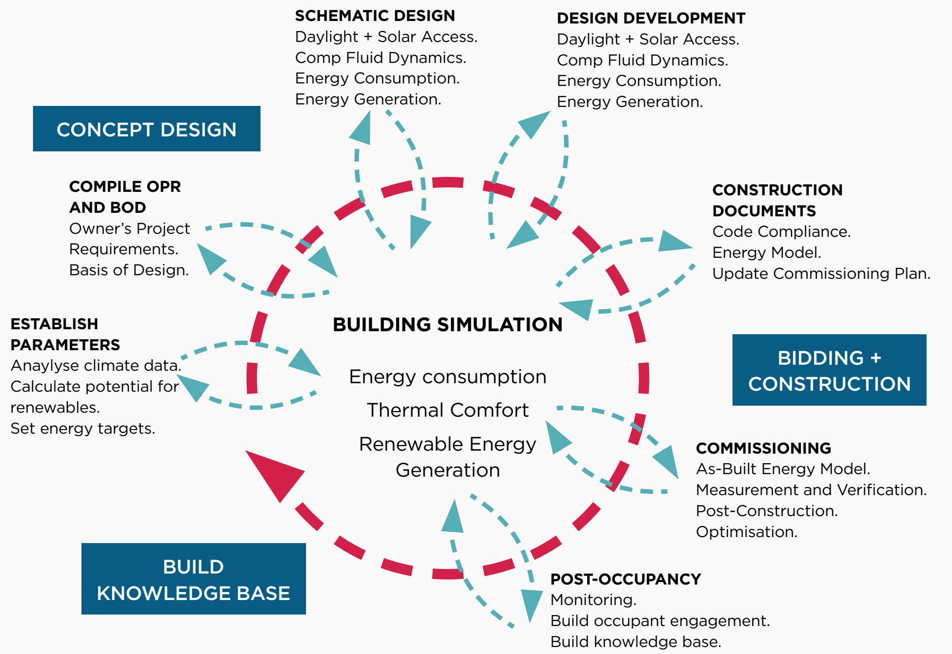
The first key to success is to instil a mindset convinced that NZC projects are achievable within budget, are a good financial investment, and are highly marketable.

This mindset must exist from project inception, and must include the client and entire project team, including the financial team. From the start, an 'energy champion' should be designated, who has authority to make decisions on the client's behalf. This should be included in the project brief.

2. Collaborate and iterate

Net zero projects demand highly collaborative synergies among those who plan, design, construct, use, operate, and maintain them. An 'integrated design' process is required, where all design and operation roleplayers are engaged from inception. The process uses iterative loops informed by building simulations and analysis to ensure that all design-team members are engaged to identify synergies and solutions.

INTEGRATED DESIGN PROCESS FOR A NET ZERO ENERGY BUILDING



Source: Achieving Zero Energy - Advanced Energy Design Guide for Small to Medium Office Buildings.

3. Have a target

The Energy Use Intensity (EUI) of a building is the predicted energy consumption of the building before any renewable energy generation (often expressed in kWh/m^2/year).

When designing a net zero carbon building, this target is continually refined, but needs to be set from concept design stages. This essentially becomes the building's 'energy budget' and informs decisions relating to building form and architecture, building services design and renewable energy.

More detail on indicative best-practice targets is provided on p.17.

Other EUI considerations:

- Find case studies - Once an initial EUI target has been set, identify local and international best-practice examples to demonstrate the tangible feasibility of this target.
- Adjust for exceptional loads and occupancy hours - buildings are unique. As such, reviews of the intended operating practices, as well as unique plug loads or building services should be factored into the EUI target as the design develops.
- Renewable energy - Note that the EUI target does not include any renewable energy generation. If the project only wishes to use on-site renewable energy to achieve NZC, the target EUI will be limited by the amount of renewable energy that can be generated on site.

4. Hire the right project team

Hiring the right team is the most important step for the success of any project and therefore is the most important step in successfully completing a zero carbon building. Zero carbon performance will not be achieved and sustained unless the team hired for the project has the expertise, creativity, and commitment needed to achieve zero carbon goals.

- A successful NZC team must also include team members with building simulation and energy modelling expertise. This is essential to help guide design decisions keeping the energy goal in mind.
- Representatives from tenant operations and facility management in the design process will ensure that assumptions around tenant energy usage and perception of comfort are more accurately taken into account.
- Designers with the skill and drive to deliver a zero carbon building are obviously critical. Ask for references from highly efficient design projects undertaken to date, and perhaps even energy performance data for these buildings.
- A successful NZC team must include a commissioning professional. This person ensures the building's systems perform to the intended efficiencies after construction.

5. Prioritise commissioning

Commissioning has a critical role in net zero carbon projects: to provide a building that satisfies the owner's intent. A commissioning agent on the design team can also provide valuable insight from the start of the process.

There must be greater commitment to the proper operation of the building post-occupancy, because net zero carbon focuses on the performance of the building. Monitoring and recording building performance data is crucial. To maintain awareness of the energy performance and assist with measurement and verification plans, it is important that properly placed sub-meters identify end-use consumption throughout a net zero project.

Continuous commissioning will help prevent energy issues from developing and the net zero carbon target shifting out of reach.

6. Educate the occupants

Occupant behavior is one of the most significant factors of uncertainty in the prediction of building energy use.

Human behaviour shapes and influences energy usage in complex and sometimes counterintuitive ways. Improving the energy efficiency of the buildings in which we live and work requires not only changes in design strategies, construction techniques, or the use of more energy efficient technologies, but also in engagement with building occupants.

Therefore, net zero projects must consider occupants in two ways:

- Consider the use of energy-related behavioral patterns and lifestyles in your design strategies and corresponding performance simulations.
- Continuously train and educate personnel looking after building operations as well as the building occupants. This can be done through human resources (HR) and communications campaigns, staff or team competitions, or screens showing energy consumption data in an accessible way.

SECTION 2

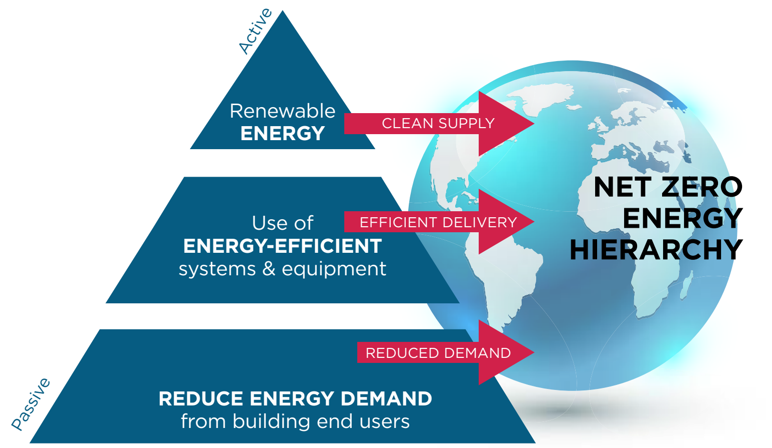
MAKING IT HAPPEN

EFFICIENCY FIRST: AIMING FOR A TARGET

Architecture 2030 describes the process of developing a NZC building as follows:

"...a NZC building dramatically reduces its fossil fuel generated energy consumption, first through building design strategies and energy efficiency measures, *then* incorporates on-site renewable energy systems and *then* procures locally produced renewable energy to meet the balance of its energy needs."

THE ENERGY HIERARCHY - BEAHRS ELP



Setting an Energy Use Intensity (EUI) target for the building is imperative from the start of the project. Below is a list of indicative Target EUI's needed to align with net zero performance for typical office buildings in South Africa's four main metros. These would represent highly efficient buildings that, depending on the space available, may be able to generate as much energy in a year as they consume.

For comparative purposes, these are presented alongside the current draft legislative energy performance benchmarks for the country (SANS 10400-XA:2020), as well as typical standard practice.

INDICATIVE* EUI TARGETS FOR OFFICE BUILDINGS IN SA

City	Target Office EUI* for net-zero performance (kWh/m²/yr)	'Draft' legislative SANS 10400-XA:2020 benchmarks for offices, (with plugloads added)** (kWh/m²/yr)	Current 'Standard Practice'
Tshwane	67.5	114	150-210
Johannesburg	67.5	96	
eThekwini	70	114	
Cape Town	50.5	90	

*Derived from Table 3-1, ASHRAE 'Advanced Energy Design Guide for Small to Medium Office Buildings - Achieving Net Zero' **The proposed SANS 10400-XA:2020 benchmarks exclude plugloads, thus 20% has been added to the proposed benchmarks for the illustrative purpose of comparison.

RECOMMENDED ENERGY USE INTENSITIES

Overall Building EUI

50-70 kWh/m²/yr

ie. **⅓** of current standard practice

10-30 kWh/m²/yr — Heating Cooling Ventilation

20 kWh/m²/yr — Tenant Loads

10 kWh/m²/yr — Lighting

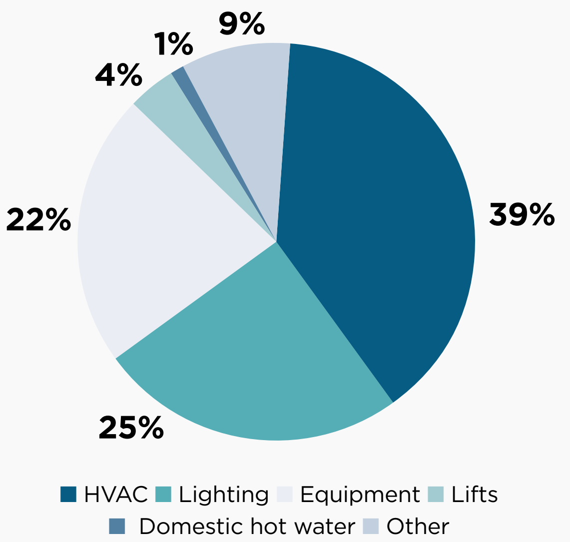
10 kWh/m²/yr — Other

Because the EUI target does not include any renewable energy generation, if the project wishes to use only on-site renewable energy to achieve NZC, the target EUI will be limited by the amount of renewable energy the site can generate. (See Renewable energy, p.31)

THERMAL COMFORT IS CRITICAL

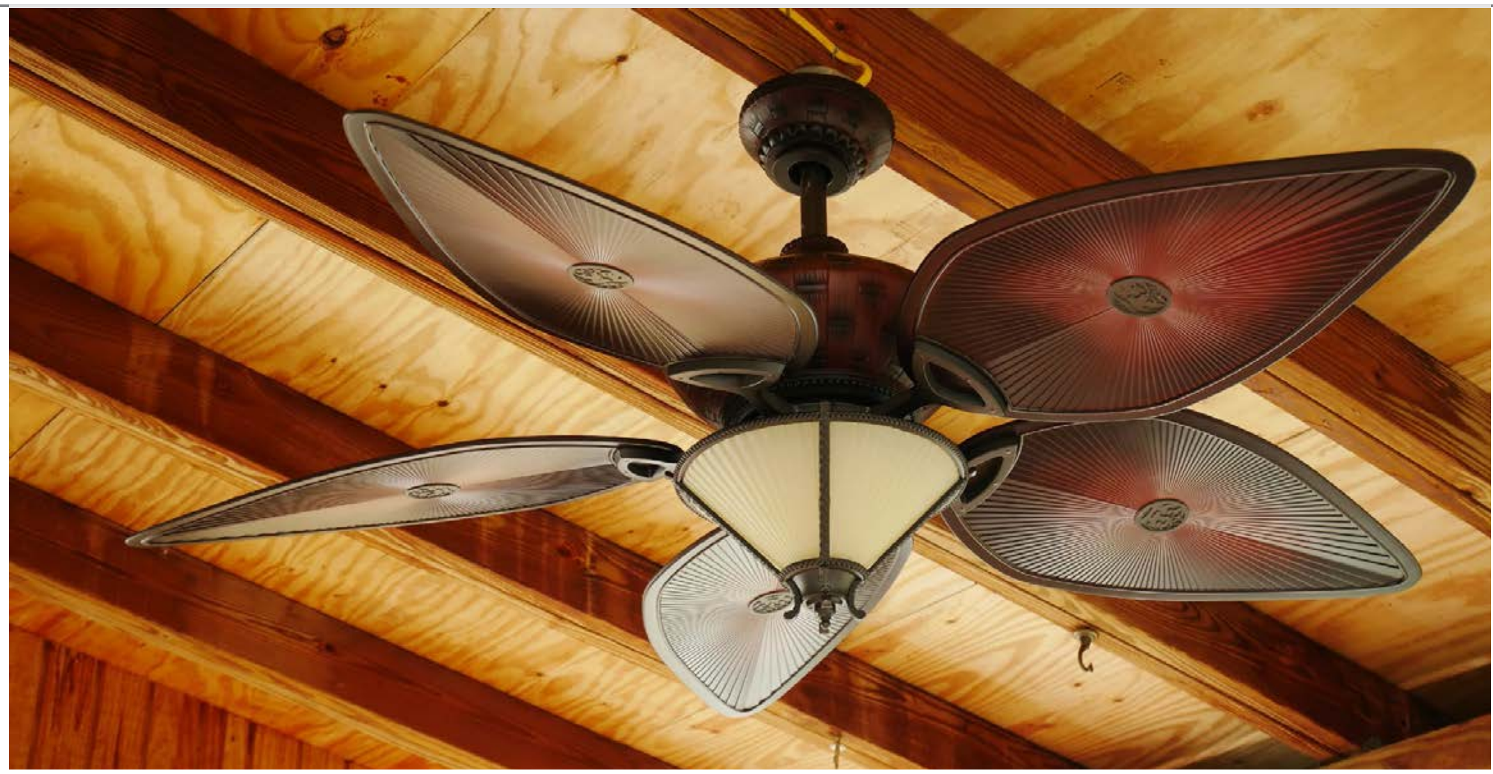
In a typical commercial office building, energy used for heating and cooling can make up 50% of consumption. As a result, the main focus of a NZC building should be to provide comfortable conditions for as much of the year as possible, without relying on active heating and cooling. This is achieved through thoughtful design of the building's 'passive' elements informed by building simulations and supported by good design.

TYPICAL ENERGY CONSUMPTION IN A COMMERCIAL OFFICE BUILDING



Source: Sow & Reap Consulting.

There are various thermal comfort standards, codes and guidelines available internationally. The ASHRAE 55 Adaptive Comfort Standard sets target operative temperature ranges which adapt according to the outdoor temperature for naturally ventilated buildings. It also takes the effect of radiant heat from direct sunlight into account. For this guideline, ASHRAE Standard 55 is primarily referenced for comfort to be achieved from naturally ventilated, mechanical active or mixed-mode systems.



Comfort without air conditioning

As shown in sections below, for much of the year, comfort can be achieved without the need for air conditioning in South Africa. In such 'naturally ventilated' scenarios, comfort is primarily affected by four factors:

Air temperature

Air temperature in a room is usually primarily affected by the outdoor temperature and the heat gain/loss from external windows and walls. As such, the primary goal is for heat gains/losses through windows and walls to be reduced.

Radiant temperature

The temperature of surfaces around you can drastically affect your thermal comfort. Radiant temperatures are thus affected by hot or cold surfaces. Direct sun on surfaces in warm conditions should thus be avoided, but can assist to lift these surface temperatures in cold winter conditions.

Air speed

The speed of air on one's skin affects perception of thermal comfort. In warm conditions, an increase in air speed (e.g. through the use of a ceiling fan) can increase the occupant comfort band by a full degree or more.

Humidity

Relative humidity between 40% and 70% does not have a major impact on thermal comfort.

High humidity environments (as found in eThekwini for example) however, can have a major effect. High humidity environments have a lot of vapour in the air, which prevents the evaporation of sweat from the skin. In hot environments, humidity is important because less sweat evaporates when humidity is high (80%+).

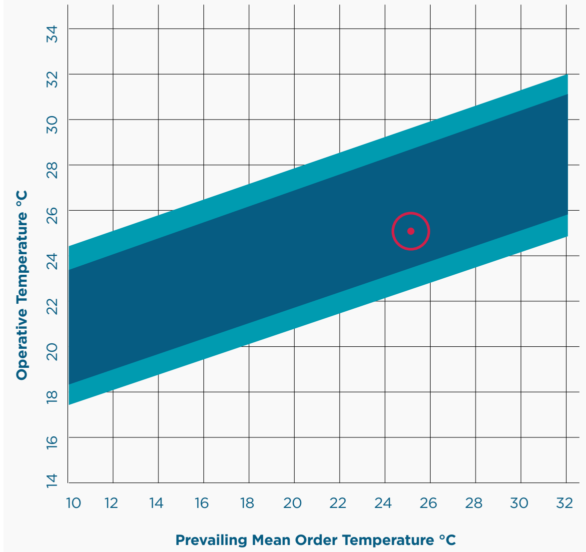
Increased air speed is thus important for comfort in high-humidity environments as this accelerates the rate of evaporation.

Calculating thermal comfort

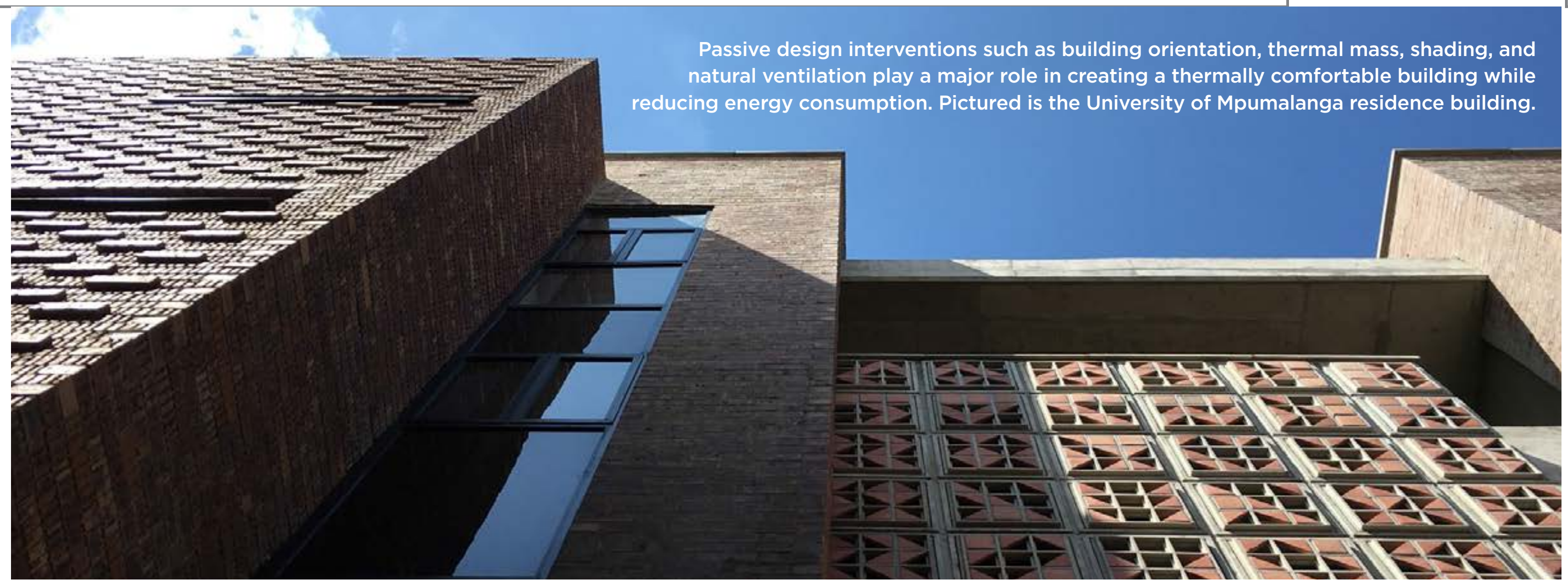
Considering these factors, thermal comfort can be predicted using the ASHRAE 55 Adaptive Comfort Standard for naturally ventilated buildings. This is typically done through building simulations, but other useful tools exist such as the 'Thermal Comfort Tool', by University of California-Berkeley Centre for the Built Environment (CBE).

By aiming to achieve comfort levels within these bands for as much of the year as possible, designers then reduce or eliminate the need for air conditioning in the building.

COMFORT BANDS FOR NATURAL VENTILATION (ASHRAE 55 ADAPTIVE COMFORT STANDARD)



**Note that 'operative temperature is a metric used to describe the mean between 'indoor air temperature' and 'mean radiant temperature'. I.e. it is the 'perceived temperature' in the space.*



Passive design interventions such as building orientation, thermal mass, shading, and natural ventilation play a major role in creating a thermally comfortable building while reducing energy consumption. Pictured is the University of Mpumalanga residence building.

BUILDING PERFORMANCE SIMULATIONS

Building performance simulation is the use of computational simulation models to represent the physical characteristics of an unbuilt or modelled building. These should be conducted during the design process, to predict and understand the building's expected operation and control strategies and energy systems. It includes, but is not limited to:

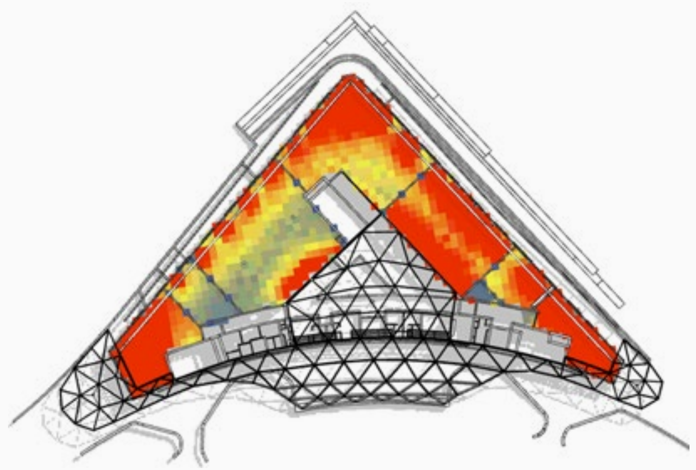
- Energy modelling;
- Artificial lighting energy and quality;
- Daylighting and glare;
- Solar performance; and
- Thermal comfort.

Apart from predicting the overall energy performance of a building, simulations can assist in optimising design decisions through the entire design process by testing the effectiveness of different strategies. This is especially true in terms of building form, shading and glazing reviews.

In the South African context, popular simulation packages include Designbuilder, IES Virtual Environment and Sefaira. A number of other software packages exist however, and this sphere is continually expanding.

An example assessing solar radiation on facades. This can be done by simulation specialists to optimise shading and glazing.

Source: PJC + Partners



An example showing that daylight and glare simulations can be used to limit the use of artificial lighting.

Source: PJC + Partners

PASSIVE DESIGN STRATEGIES

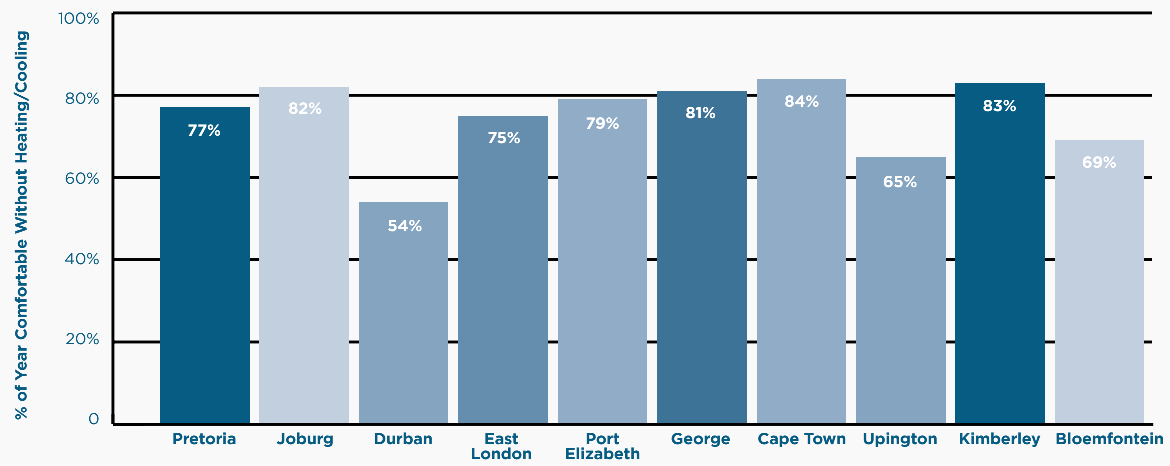
This section focuses mainly on how a comfortable indoor climate can be achieved through passive design and minimal use of active heating and cooling systems. Passive design is design that takes the local climate into consideration to maintain a comfortable temperature range in a building.

Building context and climate is vital when considering human comfort. An evaluation of the existing climatic conditions of a region will give an understanding of how one can work with these climatic elements to achieve a greater level of human comfort.

The charts below indicate how little active heating and cooling is required in South African cities if buildings are designed to meet their local climate conditions. These figures are theoretical, but provide important perspective none-the-less. They lead us to question why buildings put extensive HVAC plant in, if for potentially 75% of the time it is not needed?

Of course, this assumes that the building has been designed passively to match its environment, but still highlights massive potential for optimising heating and cooling plant size.

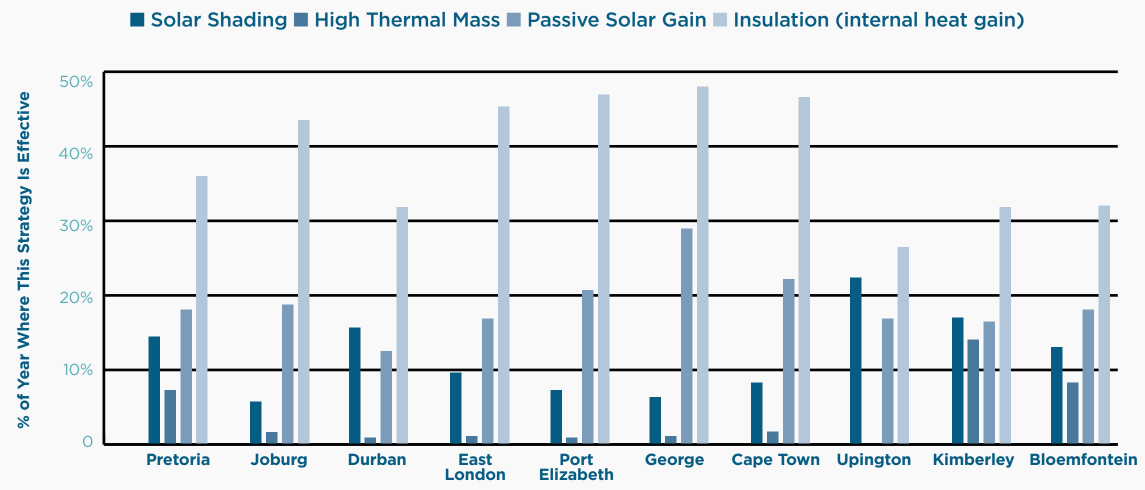
PASSIVE THERMAL POTENTIAL COMFORT OF SOUTH AFRICAN CITIES



As shown in this chart, many South African cities, can achieve thermal comfort for the majority of the year without the need for heating and cooling.

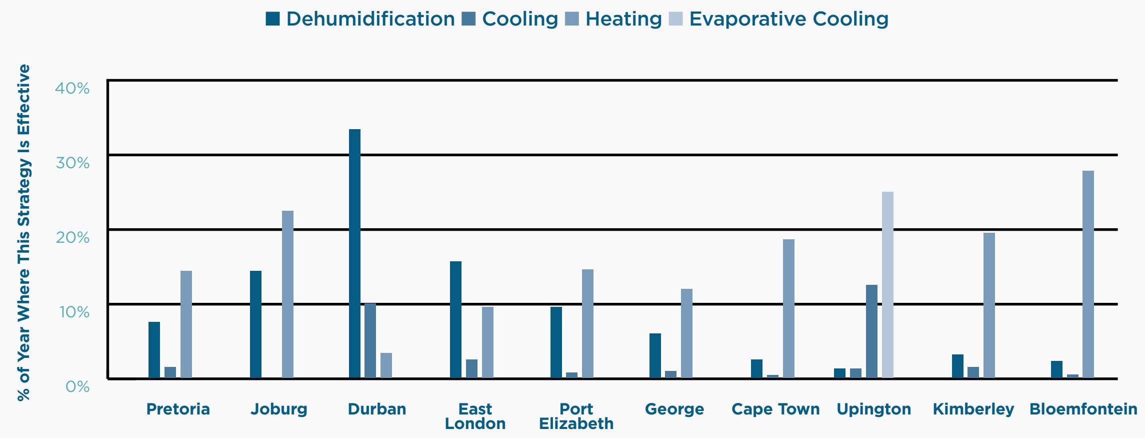
Source: Derived from CSIR Dirk Conradie's Sun, shade and natural daylight in South African town planning, with emphasis on Pretoria. 2018

EFFECTIVE PASSIVE STRATEGIES FOR SOUTH AFRICAN CITIES



This chart indicates which passive strategies are most effective for each climate zone. Note the importance of passive solar gain, indicating the importance of winter sun penetration. Some of these strategies are further explained in the sections below.

ACTIVE COMFORT STRATEGIES FOR SOUTH AFRICAN CITIES



This chart illustrates that if all available passive interventions are explored, there is theoretically little need for air conditioning in many South African cities.

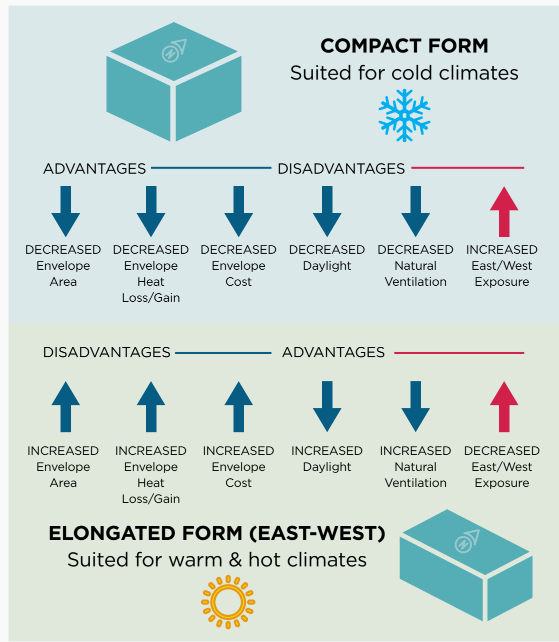
Source: Derived from CSIR Dirk Conradie's Sun, shade and natural daylight in South African town planning, with emphasis on Pretoria. 2018

In undertaking such climate reviews, there are many tools available for designers to analyse climate conditions, and provide solutions when the climate is out of the comfort zone.

For the climate analyses shown here for example, Conradie has made use of 'Climate Consultant' software, using weather files generated by means of 'Meteonorm'.

Once the climate context is understood for a project, detailed building simulations can be used to test and refine designs. Through the building performance simulations process, many passive design characteristics of the building can be tested to improve thermal comfort, reduce the need for heating and cooling, and reduce reliance on artificial lighting.

Because South Africa has several different climate zones – ranging from desert and semi-desert in the north west to subtropical on the east coast – appropriate passive design interventions and the need for active systems varies.



Source: ASHRAE's Achieving Zero Energy - Advanced Energy Design Guide for Small to Medium Office Buildings.

Some useful passive design considerations are discussed below.

Solar orientation and building form

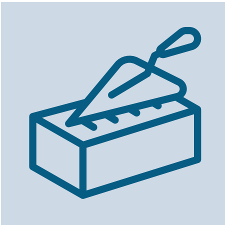
Building orientation and form should be optimised to suit the local climate. Depending on the direction or orientation of a building, certain rooms are warmer or colder. In South Africa, well used spaces should face north, with overhangs over their windows. South facing rooms are cooler, while east and west facing rooms can get very hot in summer as the low sun shines into windows without protection. This also raises the consideration of the orientation of a land parcel, at times land parcels only allow buildings to be designed with one specific orientation. As a result, the choice of a land parcel should be the first element to be considered.

Insulation

Climate-appropriate insulation should be chosen for the building envelope. The purpose of insulation in a building envelope is to limit heat flow from inside to outside or from outside to inside depending on the climate. In South Africa, the most important area for insulation is the roof.

In addition, internal heat gains must be considered for the viability of insulation in the building envelope – a highly insulated envelope in a hot climate will actually be detrimental to energy use of any active systems to maintain the internal thermal comfort.

In colder climates, internal heat gains are favourable; therefore, by providing insulation in the walls, heat escaping out of the occupied spaces is limited.



Thermal Mass

Thermal mass refers to the ability of a material to absorb and retain heat. Denser materials such as brick, concrete or stone have a high thermal mass as these require a significant amount of energy to change their temperature. This can be very beneficial in climates with large temperature swings between day and night as the heat absorbed through the day can provide heating at night, or similarly, the materials can cool down at night, providing cooling in the day. This is especially effective if combined with 'night flushing' ventilation, which uses cool night air to flush heat from a space and cool interior thermal mass.

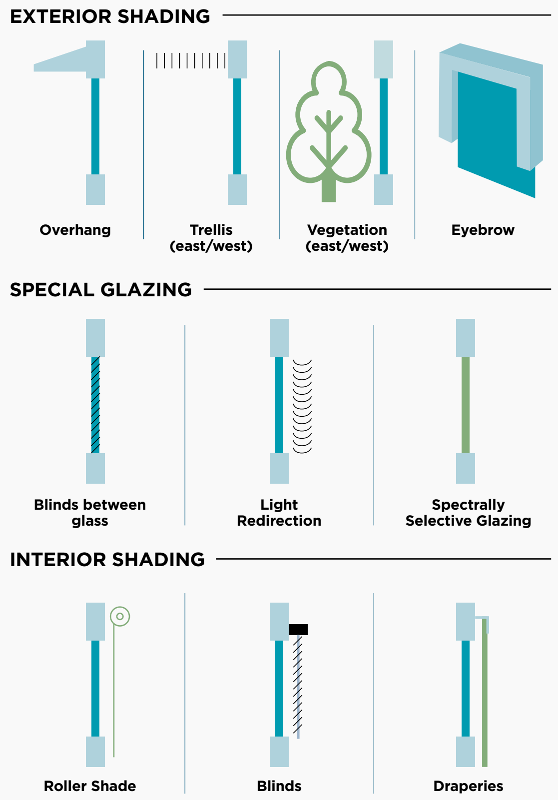
Shading

Shading should be optimised to minimise direct summer sun and let winter sun into the building. Generally speaking, shading types that exclude the sun externally during the hot period and allow it in during the cold period are more efficient.

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

Landscaping, such as deciduous trees can also be used to provide shade and reduce sunlight reflection in summer, but let the sun through in winter.

TYPES OF EXTERNAL SHADING TO CONSIDER



Source: ASHRAE's Achieving Zero Energy - Advanced Energy Design Guide for Small to Medium Office Buildings.

Glazing

Glazing window-to-wall ratios and glazing performance specifications should be optimised. Windows in sensible orientation and size can let light and winter warmth in, but very large windows can prevent the retention of warm or cool air inside when desired.

Double Glazing:

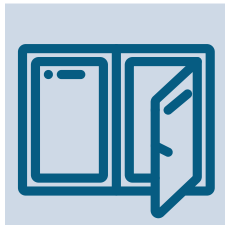
In some cases double glazing can help reduce the loss of heat through the glass (e.g. on cold South-facing facades with lots of glazing.) Note that double-glazing is not a replacement for shading however and on windows that receive a lot of summer sun, double glazing can sometimes exacerbate concerns by trapping the heat once it is in the room.

Low-E glazing:

Low-E glazing has a coating which limits the amount of infra-red and ultraviolet light that travels through the glass. This coating is often installed on the inside of the glazing to prevent internal heat from escaping the glazing in winter (not quite as effective as double-glazing, but often adequate). It also carries the benefit of reducing the solar heat gain through the glazing from outside.

Glazing with reduced solar heat gain:

For glazing that receives summer sun that can not be shaded, glazing with improved Solar Heat Gain Coefficients (often tinted to some extent) can be used to reduce the amount of heat that enters through the glass. Note however that this will also reduce the amount of heat that enters in winter. Also if single glazed, glass that receives excessive sun can heat up and have a radiant effect on those in close proximity to it.



Natural ventilation

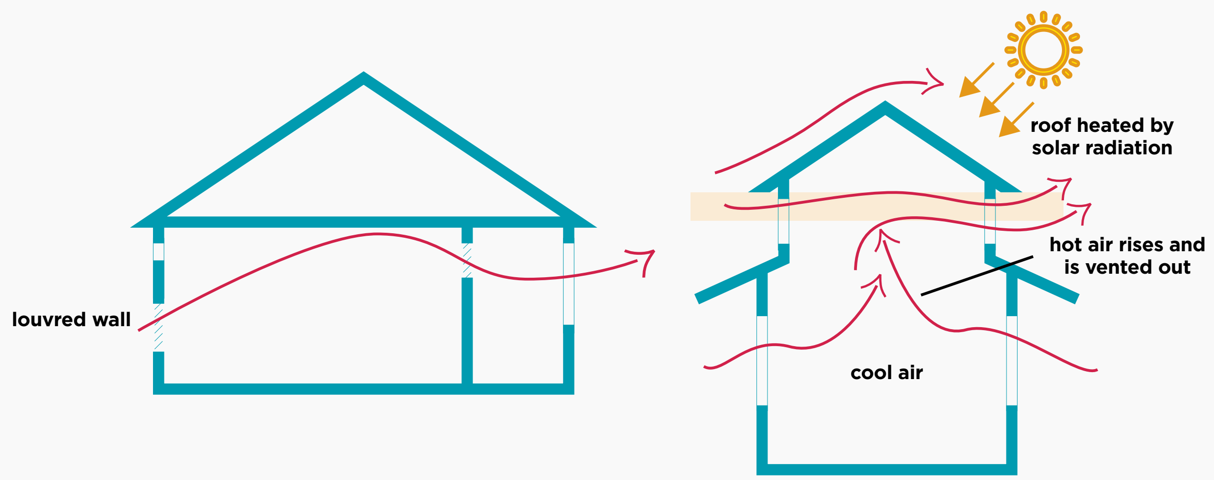
Natural ventilation opportunities should be maximised. Natural ventilation and air movement is important for human comfort as a passive design strategy and typically does not rely on any form of energy supply or mechanical installation.

The requirements for supply of fresh air are governed by building regulations as a minimum depending on the type of occupancy, number and activity of occupants and the nature of any processes carried out in the space. As a result, the size of openable windows may be stipulated in relation to the floor area or volume of the room.

The exchange of indoor air with fresh outdoor air can provide cooling, if the latter is a lower temperature than the indoor air. There are various strategies which can be applied to achieve natural ventilation:

> Building massing and shape to take advantage of surrounding context and avoiding "wind shadows".
> External features such as wing walls to redirect cool breezes into the building.
> Orientation of building openings to take advantage of prevailing wind and cool breezes.
> Building envelope features such as air bricks in addition to openable windows and doors.
> Ventilation through stack effect where warmer and lighter indoor air flow out at the top with cooler and denser outdoor air flow in at the bottom.
> Cross-ventilation to take advantage of wind patterns and breezes into the building on one side and exiting the building after air changes within the space on another side.
> Summer night cooling using night flushing in climates where there are large diurnal variations.

CROSS VENTILATION AND STACK-EFFECT FOR VENTILATION AND COOLING



Source: UN Habitat (2014).

ACTIVE DESIGN STRATEGIES

Once the building has been designed to be as passively efficient as possible, active systems are introduced. This section of the guide looks at three areas of active systems within buildings, namely:

- Heating, ventilation and cooling (HVAC);
- Lighting; and
- Tenant loads.

Heating, Ventilation & Cooling (HVAC)

10-30
kWh/m²/yr
Total HVAC

Active mechanical systems contain equipment that produces and distributes the heating and cooling, such as chillers, boilers, cooling towers, fans, pumps, and packaged heating and cooling equipment.

If a building requires an active system, the most effective and efficient solution should be found for each specific project. Modelling of HVAC systems in the early design phase should help to realise a heating and cooling strategy that is most likely to meet the desired performance for a net zero project.

Alternative control strategies can also be addressed in later design-phase energy modeling. Integration of the HVAC system with the dynamic behavior of the building, such as using precooling of the building mass or early shutdown of the HVAC system before the end of the workday, can be tested through modeling. A broader setpoint temperature range (e.g. 20-26°C) should be considered for net zero buildings, and conversations had with the client in terms of managing this expectation in achieving their NZC goals.

Below is a list of minimum recommended efficiencies and considerations for HVAC systems. These are indicative and would depend on the specific systems chosen for the project.

3.8 ISCOP*
DX Heat pump efficiency

5.5 SEER*
Chiller efficiency

1.2 W/ls
Air handling unit specific fan power

20-26 deg C
Setpoint temperatures

**Integrated Seasonal Coefficient of Performance (ISCOP) and Seasonal Energy Efficiency Ratio (SEER) are indices which designers use to gauge the efficiency of cooling and heating plant.*

Choosing the right systems

Selecting an HVAC system for a project depends on many factors, the key ones being:

- Climate and site contextual opportunities;
- Function - space usage and operational requirements; and
- Limitations - budget, spatial and building fabric.

As discussed in the 'Passive design' section of this guide (p.21), passive and low-energy solutions should be prioritised based on the local climatic conditions of the building.

On the opposite page is a list of some energy efficient HVAC strategies to consider, should mechanical heating or cooling be required for your building.

System	Efficiency Ranking	Description	Best suited to...
Ceiling fans	★★★★★ ★★★★☆	To improve summer comfort in naturally ventilated buildings, ceiling fans can be very effective, especially in tropical climates where humidity is high.	Naturally ventilated buildings. High-humidity climates.
Mixed-mode ventilation	★★★★★ ★★★☆☆	Mixed-mode systems allow for natural ventilation when the climate is suitable, and mechanical cooling when required.	Systems can either be automated, or can simply notify occupants when windows should be opened or closed. Buildings where mechanical heating/cooling is only needed for certain times of the year.
Displacement ventilation	★★★★★ ★★☆☆☆	Air is introduced at a low-level and extracted at high-level, allowing for cooling of just the occupied zone, as opposed to mixing and cooling all air in the room.	Because heat rises through convection, much of the heat from lighting and equipment is extracted, reducing the cooling load. This solution improves air quality as pollutants are extracted at high-level. Applications where heating and cooling loads are fairly constant through the day. Double-volume spaces.
Radiant heating or cooling	★★★★★ ★★☆☆☆	Because thermal comfort is affected by both radiant heat and space temperature, it is not always necessary to cool or heat the entire room to setpoint temperature. By creating warm or cool surfaces such as floors, ceilings or structure, comfort can be achieved even if air temperature is outside typical setpoint bands. Examples include underfloor heating, chilled beams or structure.	Applications where heating and cooling loads are fairly constant through the day. Applications where high humidity is not a concern.
Evaporative cooling	★★★★★ ★★☆☆☆	Evaporative cooling offers very high efficiencies in drier climates. Care should be taken with respect to legionella risk management. Again, water usage should be considered however.	Buildings with abundant non-potable water.
Water-cooled chillers	★★★★★ ★☆☆☆☆	Water-cooled chillers offer high efficiencies in comparison to their air-cooled counterparts. Water usage can be high however.	Buildings with abundant non-potable water.
VRF heat pumps with heat recovery	★★★★★ ☆☆☆☆☆	Variable Refrigerant Flow heat pumps allow for heating and cooling only to the zones that require them. If accompanied with good occupant training, these systems can be highly efficient. Additionally, where simultaneous heating and cooling is required in a building, heat recovery can be achieved if the zones are matched correctly to outdoor units. This results in further efficiencies, especially in dual-orientation buildings.	Buildings with zones that have varying heating and cooling loads. Buildings with zones that have varying occupancy.
Carbon monoxide (CO) control of basement fans	★★★★★ ☆☆☆☆☆	Basements should be naturally ventilated wherever possible. Where mechanical ventilation is required, CO sensing and control will dramatically reduce energy consumption by reducing basement ventilation rates when CO levels are low. This can typically save 50% off of the basement fan energy consumption.	Basements where natural ventilation can not be achieved.

Lighting

10
kWh/m²/yr
Office Lighting

For net zero carbon projects, the aim is to get the electrical requirement for lighting as low as possible. This is not only about using the latest technology. Much can be done through passive design principles.

Some typical benchmarks to aim for in net zero buildings are provided in this section, as well as a list of efficient lighting strategies.

4 W/m²
Cellular office lighting power density
2 W/m²
Basement parking lighting
0.5 W/m²
Outdoor and after-hours lighting
Occupancy & Photocell
Efficient control strategies required

Source: ASHRAE's Achieving Zero Energy - Advanced Energy Design Guide for Small to Medium Office Buildings.

Daylighting
By planning with building simulation software, the amount of natural light in the building can be maximised. This minimises the need for electrical lighting. It should, however, be achieved without increasing the heat gain in the building.

Reflectances
The reflectance values of surfaces in a space play a large role in the efficiency of lighting in providing lux levels (the unit measuring the intensity of light hitting a surface - higher lux levels are generally required in an office where reading, for example, will take place). The choice of interior materials, paints and coverings for surfaces can influence these levels. Below are some generic guidelines on reflectance levels for maximising lighting levels:

- Ceiling reflectance should be at least 80% (preferably 90%). I.e. smooth white
- Average reflectance of the walls should be at least 50%
- Floor surfaces should be at least 20%
- Cubicle partitions should also have a reflectance of at least 50%. Partitions between cubicles that are parallel to the window wall should be at least 50% translucent or be limited in height to maximise daylight potential past the first cubicle.

Power consumption
Light-emitting diode (LED) technology has transformed lighting energy efficiency in recent years. While many fitting options are available to achieve certain lux levels, the power efficiency thereof is then often targeted in terms of watts per m² - referred to as lighting power density (LPD). The table below indicates best-practice lighting power densities for typical commercial buildings.

For outdoor spaces and after-hours lighting, 0.5 W/m² is generally recommended.

RECOMMENDED LIGHTING POWER DENSITIES FOR NET ZERO CARBON BUILDINGS

Space Type	Recommended LPD (W/m²)	'Draft' legislative SANS 10400-XA:2020 benchmarks for offices (W/m²)	Current 'Standard Practice' for offices (W/m²)
Open plan office	3	8	6-8
Private office	4		
Conference room	8		
Corridor	4		
Restroom	3		
Building average	4		

Controls
Aside from the actual efficiency of the light fixtures, lighting controls can help realise significant energy savings. The table below provides some context for some typical control strategies to consider.

Control Type	Energy Saving Potential
Manual switching	Occupants are empowered to turn lights off when leaving the room.
Manual dimming	Occupants are empowered to dim lights to improve comfort in the space. Combined with a manual switch, a dimmer creates a single preset that provides persistence in savings.
Occupancy / vacancy sensor	Provides persistence in energy savings due to automatic OFF. Placement of sensor is critical; it must "see" the entire space and the user must not be blocked by furniture. Option — set sensor to turn lights to 50% ON initial trigger, because occupants may find lower light levels acceptable.
Daylight dimming	Automatic control that adjusts the lighting in response to available daylighting in the space. Provides persistence in energy savings in areas with daylighting. Manually operated blinds reduce savings.
Task tuning	Often the initial light level can be reduced because the designed/desired light level is higher than required due to luminaire spacing and lumen maintenance factors. Savings are dependent on the tuning level but can be as high as 25%.
NLC (networked lighting control) or PoE (power over ethernet)	Savings can be high because all luminaires and controls are integrated together. These systems include the ability to task-tune on a luminaire/ group or space depending on the granularity of the sensors. These systems generally provide system monitoring.
LLLC (luminaire-level lighting control)	Daylight and occupancy controls are integrated into each luminaire. Luminaires have built-in wireless network interfaces. Due to the granularity of the controls these systems have the highest potential energy savings.
Exterior photo control	Daylight sensor that turns the light on around dawn and off around dusk. Should be a minimum requirement for all outdoor lighting.

Source: ASHRAE's Achieving Zero Energy - Advanced Energy Design Guide for Small to Medium Office Buildings.

Tenant Loads

20
kWh/m²/yr
Tenant Loads

To reduce plug loads, two principal approaches are used:

- Select equipment with lower power demands.
- Control equipment so that it is off when not being used.

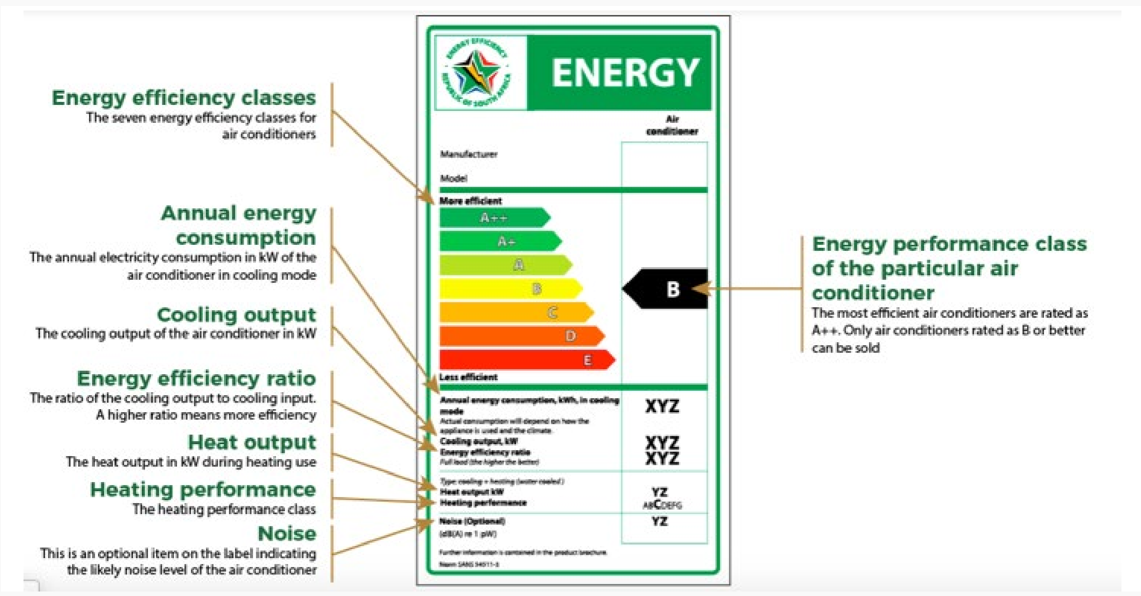
8 W/m²
Overall tenant loads*
0.5 W/m²
ICT plug loads
2 W/m²
After hours plug loads*

This section provides some useful benchmarks to aim for (left) as a designer, as well as guidance as to selecting efficient tenant equipment

**Source - LETI Climate Emergency Design Guide.*

In general, equipment should be selected to meet 'Energy Star' or 'EU A+' or A+++ (in the case of the South African Energy Efficiency Label) ratings wherever possible.

An example of a label for an air conditioner is shown below for the South African Energy Efficiency Label. Labels for various categories of appliances differ depending on the functioning of the appliance, however, all labels include seven energy efficiency classes and the energy efficiency class of the particular appliance is labelled clearly.



An example of the South African Energy Efficiency Label.
Source: Savingenergy.co.za

RENEWABLE ENERGY

Once the building is as energy-efficient as possible, the remaining energy demand of a net zero carbon building must be met through on-site renewable energy (RE), or if this is not possible, off-site renewable energy.

Rooftop solar photovoltaic (PV) is the most cost effective way to generate RE on-site in South Africa. Where this is not possible – due to lack of roof space, a shaded roof, grid limitations or other reasons – off-site RE can be procured.

This is a rapidly changing landscape and the RE approaches for net zero carbon buildings should remain flexible and dynamic rather than technology prescriptive.

Solar PV

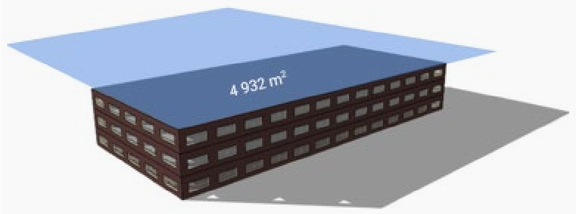
The cost of rooftop solar PV systems have plummeted in the last decade. With South Africa's abundant solar resource and rising electricity costs, these systems are now financially attractive for many building owners. It is estimated that over 6000 solar PV systems have already been installed in South Africa (CSIR & SAPVIA, 2019).

Ballpark calculations on the payback period of a rooftop solar PV installation indicate that commercial customers can have payback periods as low as five to eight years and residential customers eight to twelve years. Considering that solar PV systems typically last 20 years, many building owners are satisfied with these returns and this has led to rapid uptake. In the case of commercial property, the income received from supplying this energy to tenants can also have impressive impacts on the profitability and financial return of projects.

Innovative financing options have emerged to help building owners reduce the upfront capital costs of a solar PV system. There are companies that will fund and install a solar PV system on a building's roof, allowing the building to purchase the energy from the company through a power-purchase agreement. Most of South Africa's large banks now offer attractive lending options to cover the upfront costs, and there are other initiatives emerging to repay the cost of a solar PV system through a building's rates bill. These financing mechanisms are making it much easier to install rooftop solar PV.

STANDARD ENERGY EFFICIENCY

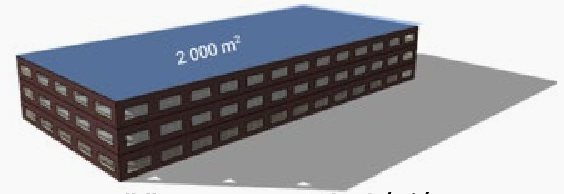
Solar PV area needed to offset building's energy consumption



Building consumes 200 kWh/m²/year (SANS 10400:XA 2011 compliance)

OPTIMISED ENERGY EFFICIENCY

Solar PV area needed to offset building's energy consumption



Building consumes 81 kWh/m²/year

**Based on 3 storey 6000m² office building in Johannesburg with 30 deg North-facing roof.*

The amount of roof space is naturally a constraining factor. The example above is for a three-storey building of 6000m² in Johannesburg. If on-site generation from rooftop solar PV is used to achieve a net -zero building, the building would need to consume no more than 81 kWh/m²/year. While this level of efficiency is certainly possible, the graphic shows that it does require efficiency well beyond current building code.

This image shows that simply adding renewable energy to a conventional design will not deliver an NZC building. To the contrary, by far the largest energy consumption reductions will come from non-technical solutions (ie passive design strategies), such as orientation, glazing ratios, etc. This also is the key to a cost-effective NZC building.

A team of solar PV installers preparing to harness the sun from a 2.7MW installation on the rooftop of the Emperors Palace Casino in Johannesburg.

Building integrated solar PV, in the form of roof tiles and windows, is also gaining traction in international markets and these technologies could expand a building's solar generating capacity beyond the limitations of rooftop systems.

Besides roof space limiting the amount of solar PV that can be installed at a particular site, a second limiting factor is the electricity grid's capacity. Each portion of the electricity grid can only handle a certain amount of grid-connected solar PV before operating parameters are exceeded. The NRS 097-2-3 specification (Small-Scale Embedded Generation: Simplified Utility Connection Criteria for Low-voltage Connected Generators) shows how this can be assessed. If systems are beyond the parameters in this specification, more detailed grid studies may be necessary before the installation can go ahead.

It is often possible to be net zero carbon within the NRS 097-2-3 parameters, although this is very site specific and depends on the consumption characteristics of the customer. The higher the energy (kWh) consumption relative to the size of the connection (in kW or Amps), the less the site is likely to be able to generate enough to offset its electricity use.

RE system installers are usually familiar with the NRS 097-2-3 criteria, and many municipalities have specific guidelines around this. It is advisable to contact your municipal electricity department in the design phase of a project to obtain their guidelines around establishing the grid's capacity for on-site generation.

Registering a solar PV system with the municipality

To ensure systems are safe and legal, all solar PV systems must be registered with the municipality and comply with their conditions. Among the most important conditions are those relating to the inverter. They must comply with the NRS 097-2-1 specification, which stipulates acceptable power quality and ensures safe grid connection. Inverters should be checked for compliance with this standard before purchase. Registered systems can feed electricity into the grid (export) in most municipalities. The municipality then credits the account for the exported electricity.

Grid connected RE generation may require a license from, or to be registered with NERSA (National Energy Regulator of South Africa) under certain circumstances. Currently, the Schedule 2 Exemption Notice of the Electricity Regulation Act (ERA) indicates that in general, all systems under 1MW do not need a license. Systems from 100kW to 1MW need to register with NERSA, while systems under 100kW do not need to register with NERSA, although all systems must register and comply with municipal distributor conditions. Schedule 2 of the ERA also allows systems under 100kW to generate as much as they want and remain license exempt, but between 100kW and 1MW systems require a license if they generate more than they consume from the network (i.e. they need to be net consumers to be exempt).

The easiest way to find out more about solar PV is to contact an industry-accredited solar PV installer. The PV GreenCard is an initiative to promote safe and quality solar PV installations – find an accredited installer at www.pvgreencard.co.za. This is a South African Photovoltaic Industries Association (SAPVIA) endorsed programme. The PQRS PV Performer Platform (P4) is another quality assurance programme, listing certified solar PV installers.

Renewable energy incentives

Building owners should also be aware of incentives offered by the government for energy efficiency and renewable energy. Solar PV systems can be depreciated in the first year for tax purposes (Section 12b of the Income Tax Act).

Other on-site renewable options

Precinct developments and larger commercial buildings may have sufficient electricity demand to justify the installation of a biogas plant or a small wind farm (depending on available space and other factors). As with solar PV, these technologies will need to be registered with the municipal electricity department and can feed into the grid and will be credited at the local feed-in-tariff. However, these technologies remain costly in most markets at building level.

Off-site RE

In cases where roof space is limited for PV (tall commercial buildings), the building's roof is shaded by other buildings or the grid limits the amount of on-site RE, off-site RE can be procured. Mechanisms for the procurement of off-site RE are emerging. Two promising mechanisms are: (1) wheeling of electricity; and (2) municipalities selling RE directly to customers.

An example of electricity wheeling would be where a warehouse with a large roof, covered in solar PV, sells the excess electricity to a building in the city. The building would pay the warehouse for the electricity as well as paying the city for the use of the grid to transport the electricity. This building is thereby consuming RE, and can contribute towards NZC. Energy trading companies are already facilitating these types of transactions in South Africa.

A second mechanism for off-site RE procurement is where a municipality sells RE directly to customers. While this mechanism does not currently exist, municipalities have been given permission to procure electricity directly from independent power producers, and this type of RE procurement is expected to become more common.

"Net zero carbon capable" refers to buildings that are as energy efficient as NZC buildings but don't have renewable energy on-site. These buildings could access renewable power generated elsewhere, but if this is not possible or mechanisms do not exist, these buildings remain "NZC capable".

RESIDENTIAL CONTEXT

Delivering a successful net zero carbon home project relies on many of the same principles as a commercial building.

One of the major differences is that in a residential home the biggest energy consumer is usually the demand for heating water, and not HVAC as in commercial buildings. The project team or homeowner should identify ways to heat water more efficiently. There are a number of ways to do this, including installation of a solar water geyser or heat pump technologies.

Zero carbon homes also need to start with a strong commitment. This is followed with smart design that takes the prevailing climate into consideration and uses passive design principles that will lower energy consumption. Conducting building performance simulations for energy modelling will also help to achieve this. As with commercial projects, the aim is to ensure that homes are thermally comfortable and naturally ventilated, thereby negating the need for artificial heating, cooling and ventilation.

All lighting should be energy efficient (3 W/m^2) and energy efficient appliances and electronics should be used in the house (look for energy-labelled appliances).

Once the energy requirement of the home is as low as possible, use renewable energy to provide the energy for the house. Grid-tied solar PV is currently the most popular and cost effective option for homes in South Africa.

The peak times for energy use also usually differ between commercial and residential buildings. This often means that the biggest energy requirements in the home are in the early mornings and evenings, when the sun is not at its strongest and a solar PV system may not be generating at its peak. This often necessitates an energy storage system (battery bank), which needs to be managed carefully by the homeowner.

SECTION 3

CASE STUDIES

OFFICE BUILDINGS

THE GREEN BUILDING

Size: 700m² (590m² lettable)
Design/Construction: 2003/4
Net zero carbon achieved: October 2018
Energy consumption: 30-50 kWh/m²/year
Energy generation: 14kWp rooftop solar PV (20 640 kWh/y)
Location: Westlake, Cape Town

Designed and built back in 2004, the Green Building bolstered it's rooftop solar PV system in 2018, bringing it to net zero carbon status. The highly energy efficient building generates as much renewable energy as it consumes over a year.

The office of Sustainable Energy Africa, the building was designed to be as green as possible. Thermal modelling was done and passive solar design principles were applied - roof overhangs and large windows to maximise natural light for example. The central wooden floor was designed with gaps and, coupled with wind-powered extractor fans, this achieves natural ventilation. No central heating or cooling is required, although in midsummer and midwinter occupants use personal heating and cooling for their own comfort. Personal fans and small heaters are less energy intensive than a central thermal regulation system.

When originally built in 2004, electricity was cheap and solar PV did not make financial sense. A small 2kW system was however installed for emissions reduction. By 2014, the cost of solar had decreased, and the 2kW system was replaced with a 4kW system, which generated a quarter of the building's energy requirement.

In September 2018, a further 10kW of solar PV was added, bringing the system size up to 14kW. The building now generates as much electricity as it consumes on average over a year. This is in line with the City of Cape Town's regulations, which don't allow buildings to generate more than they consume.

A simple payback of four years is expected for the 10kW system. Total cost for the new 10kWp system was R159 000 excluding VAT. A cheaper system could have been installed, but a decision was made to oversize the inverter to enable future expansion, and use hi-performance bifacial panels. The cost of energy (from the solar system) over 10 years is 45c/kWh (simple) and the cost of energy over 25 years is 10c/kWh (simple). This compares with the current (2020) average electricity tariff in South Africa of 106.8c/kWh.

By leveraging section 12b of the income tax act, this incentive also effectively saved the green building R44 000 in the relevant tax year.

MDA HEAD OFFICE

Size: 912m²
Design/Construction: 2018/19
Net zero carbon achieved: GBCSA Certified April 2019
Energy consumption: 29.5 kWh/m²/year
Energy generation: 18kWp rooftop solar PV (32 106 kWh/y)
Location: Houghton, Johannesburg

MDA's new head office incorporated passive design and energy efficiency features before renewable energy systems were even considered.

Designed by Activate Architecture, with sustainability consultants Solid Green Consulting, this building is three times more efficient than a standard office building in South Africa.

Office areas are designed to be naturally lit for much of the year, thereby reducing reliance on electrical lighting, and high-performance double glazing has been used for all curtain walls. The passive design principles ensure that even though the building has an air conditioning system, it only has to be used on really hot days. Staff can open windows for fresh air and comfort.

The variable refrigerant flow (VRV) HVAC system installed has heat recovery with reverse cycle heating – the most efficient system available at the time.

LED lighting features throughout most of the building, and occupancy lighting controls minimise consumption. Submetering and monitoring systems for water and energy facilitate ongoing management of these resources.

An extensive solar photovoltaic (PV) system was installed on the roof. It completely offsets the building's electrical needs.

RESIDENTIAL

78 CORLETT DRIVE

Size: 2 167m²
Design/Construction: 2017/2018
Net Zero Carbon achieved: GBCSA Certified October 2017
Energy consumption: 73.4 kWh/m²/year
Energy generation: 55kWp rooftop solar PV (92 000kWh/y)
Location: Illovo, Johannesburg

This two-storey office has an upper ground floor with a mix of cellular offices, co-working spaces and social and formal meeting spaces, centred around a coffee bar within a naturally lit, triple volume atrium. On the first floor are more co-working spaces and larger formal offices, where owner and developer Legaro Properties has it's office.

The building was designed by Daffonchio & Associates Architects with sustainability consulting by Solid Green Consulting. Detailed energy modelling in the design stages helped to ensure maximum energy efficiency.

The facade serves a strong green purpose. The shading louvres act as a dynamic facade element and passive shading device. They allow for natural light to pervade the building, without the associated heat and glare. The north facade features external fixed shading, while the east and west sides of the building have movable shading blinds, and mesh allows vegetation to grow as shading on the south side of the building. The atrium also brings in natural light.

Efficient lights and sensors were prioritised. When compared to a notional building model's SANS 10400 energy requirements, 78 Corlett's design showed an improvement of 100%. Individual lighting switches are provided for all individual or enclosed spaces for greater flexibility. The office lighting design achieves an average maintained illuminance level of no more than 400 Lux.

Efficient HVAC and fans, air cooled chillers and hideaway fan coil units enabled a 25% energy efficiency saving when compared with a notional building. Hot water is provided through small high performance electric under counter geysers installed in each bathroom, which also mitigate the need for long stretches of insulated hot water pipes.

The project has a 55kWp photovoltaic rooftop installation, which provides enough renewable energy for the project to meet its everyday needs.

JOE SLOVO SUBSIDISED HOUSING

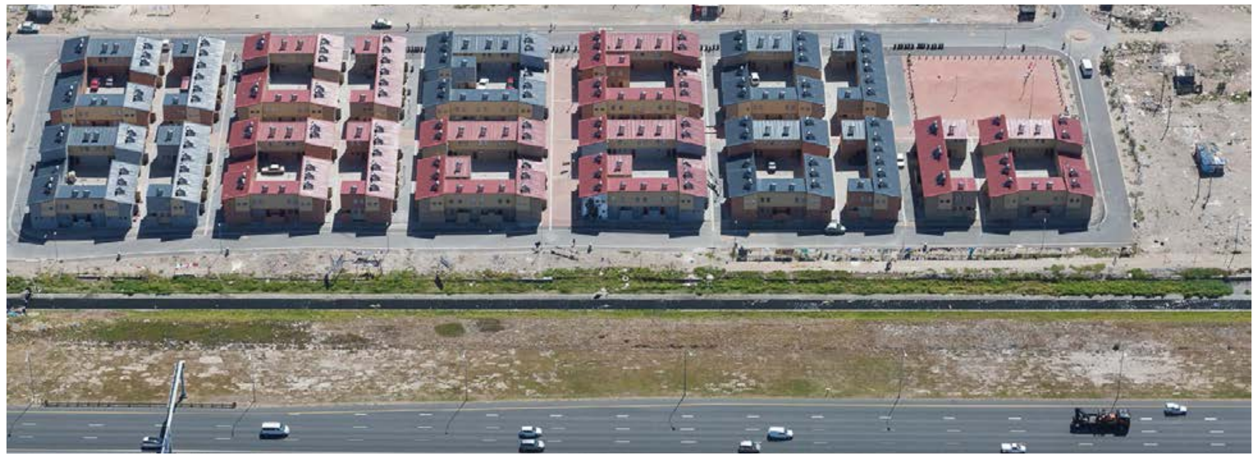
Size: 40-50m² per dwelling
Design/Construction: 2015
Net zero carbon achieved: "Net zero capable" since occupation in 2015
Energy consumption: 35-50 kWh/m²/year
Energy generation: 0. Requires off-site RE to achieve NZC.
Location: Langa, Cape Town

The Joe Slovo settlement is situated in the suburb of Langa, 10 km East of Cape Town CBD, on City-owned land off the N2 highway. It is a national flagship housing project of the Department of Human Settlements (DHS), showcasing a new approach to sustainable housing delivery in the country under the Integrated Reconstruction and Development Programme (IRDP) initiative.

With support from international donors (DANIDA) and top-up funding from the Western Cape Provincial Government, solar water heaters were installed on all households. Energy efficient CFL lights were provided, and the common courtyard area has solar PV powered lighting.

The housing units have been designed with thermally efficient features. The houses are double storey, and have shared walls which have been plastered and painted on the outside. There are roof overhangs to shade windows in summer but allow solar gain in winter, and orientation is north-facing as far as is possible in a complex development. The thermal design was optimised with the help of a computer modelling package.

The argument can be made that every low income household is net zero capable due to energy poverty. However, the Joe Slovo settlement is an example of how energy efficiency can increase energy services without increasing energy expenditure.



INDUSTRIAL

LORDS VIEW INDUSTRIAL: PREMIER FOODS FACILITY

Size: 19 366m^2
Design/Construction: 2018
Net zero carbon achieved: GBCSA Certified January 2020
Energy consumption: 27.1 kWh/m^2/year
Energy generation: 690 kWp rooftop solar PV (299 259 kWh/y)
Location: Midrand, Johannesburg

The majority of the space in this GBCSA Net Zero Carbon-certified industrial structure is dedicated to warehousing. With sustainability consulting from Ecolution Consulting, energy efficiency was prioritised upfront and a mix-mode ventilation system ensures both mechanically ventilated and naturally ventilated spaces. Individually addressable lighting with occupancy sensors also feature.

There is an integrated building management system, which records and logs all energy and water usage within the building and is displayed in real time.

To improve indoor air quality, all paints, adhesives sealants and carpets have low VOC emissions.

The rooftop photovoltaic system provides more energy than the entire Premier facility consumes. The 690kW grid tied system consists of 2 090 Trina Solar PV modules with a 330W capacity. The total area of the PV system covers 4 055m^2 and yields 1197 000 kWh/y. The PV system also provides power to up to three neighbouring facilities and, 25% portion of the total area is dedicated to the Premier Foods Facility. This portion equates to a total production of 299 250 kWh.

GREENFIELD INDUSTRIAL PARK

Size: 21 000m^2
Design/Construction: 2016
Net zero carbon achieved: GBCSA Certified October 2017
Energy consumption: 26 kWh/m^2/year
Energy generation: 290kW rooftop solar PV (479 300 kWh/yr)
Location: Airport Industria, Cape Town

Sustainable design principles were incorporated into this industrial facility from the start of the process. The building harnesses as much natural light as possible and all lighting is energy efficient, with occupancy sensors installed across the whole development. Green building consulting for this project was done by Sow & Reap Green Building Solutions and Misplon Green Building Consulting.

Office areas are conditioned with highly efficient VRV (Variable Refrigerant Volume) air conditioning systems, which have an energy efficient heat recovery feature.

The 2640-panel rooftop solar PV plant generates 290kWp of renewable energy. One of the biggest challenges on this project was getting the plant up and running, owing to lack of clarity from the national utility regarding registration of the PV system and whether a license was required from the regulator. New gazetted amendments to the Energy Regulation Act permit self-consumers below 1MW to generate without a license. This makes registration of systems easier now.

TWO DAM SUSTAINABLE

Size: 359m²
Design/Construction: Old farm buildings refurbished, extended 2014-2016, recirculating aquaculture system completed in 2015
Net zero carbon achieved: GBCSA Certified October 2017
Energy consumption: 15.52 kWh/m²/year
Energy generation: 31kWp solar PV array, 1kWp hydropower system (26 000kWh/y)
Location: Montagu, Western Cape

This off-grid and GBCSA Net Zero Carbon-certified trout farm and self-catering accommodation is tucked away in the Langeberg mountains of the Western Cape.

The small business and family home relies on 100% LED lighting and only energy efficient appliances. The buildings are naturally ventilated and cool roof paint was used. Solar water geysers are used for water heating. Low head recirculating pump systems are used for the aquaculture component of the business.

Most of the renewable energy required is supplied by a 31kWp solar array. A 1kWp high pressure low volume pelton wheel turbine provides hydropower. A battery bank of 72 batteries has a capacity of 172.8 kWh of which only 50% should be depleted. Batteries are charged by solar, hydro and gas if necessary.

Because the operation is not connected to the national utility's grid, a 10kW LPG generator is used on extended cloudy days, to supply the shortfall of power demand and charges the batteries simultaneously. This is offset through the purchase of verified carbon credits. The project supports the Kariba REDD+ reforestation project and the purchase of these credits was facilitated through a broker (Impact Choice) who ensures that the transaction is legitimate. This ensures the net zero carbon status of the project.

Further Reading

- ASHRAE's *Achieving Zero Energy - Advanced Energy Design Guide for Small to Medium Office Buildings* (2019)
- CSIR Dirk Conradie's *Sun, shade and natural daylight in South African town planning, with emphasis on Pretoria* (October 2018)
- Sustainable Energy Africa's *Sustainable energy solutions for South African local government, a practical guide* (August 2017)
- World Green Building Council's *Advancing net zero: WorldGBC net zero carbon buildings commitment – detailed guidance* (January 2019)
- Navigant Research's *Creating Zero Carbon Communities: The Role of Digital Twins* (Q4 2019)
- City of Cape Town's *DEVELOPMENT MANAGEMENT INFORMATION GUIDELINE SERIES: Resource efficiency for development* (November 2019)
- City of Joburg's *Design Guidelines for Energy Efficient Buildings in Johannesburg* (2008)
- London Energy Transformation Initiative's (LETI) *Climate Emergency Design Guide: How new buildings can meet UK climate change targets* (January 2020)
- National Department of Environmental Affairs *South Africa's National Climate Change Response: White Paper*
- National Planning Commission: *National Development Plan 2030: Our Future, make it work.*

- C40 Cities Climate Leadership Group: **c40.org**
- Sustainable Energy Africa: **sustainable.org.za**
- Green Building Council South Africa: **gbcsa.org.za**
- American Society of Heating, Refrigerating and Air-Conditioning Engineers: **ashrae.org**

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