



The  
Green Building  
Handbook  
South Africa Volume 11  
The Essential Guide

# GREEN BUILDING

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R150.00 incl. VAT



# MENLYN SHOPPING CENTRE

## PHASE 2

### Continuation

Phase 2 commenced with demolitions of the existing Checkers Hyper & associated components, making way for a two level mall, linking the existing end portions of the centre. This 'infill' provided an opportunity for simplification of the mall around new reference points to improve visibility and circulation.

### A place for people

Orientation within this environment has been provided via use of spaces like the keyhole malls, nodes, public spaces & entrance hierarchy.

Links at the upper levels provide intimate 'people spaces' with a sense of human scale whilst retaining a direct link to the atrium mall.

This relationship combined with the association to the outdoors via the green lung known as Central Park, reaffirms Menlyn is about people and their experiences, be it shopping, socialising, dining or merely spending time out.

Mass Transit Commuters, the elderly, Cyclists, Motorcyclists, VIP's and parents have been adequately catered for.

### Seamless integration

The original mall spaces were remodeled to mimic that of the newly constructed malls, achieved through the reconstruction of ceilings, concealed LED lighting, column & floor treatment and the new rooflights.



### Moving forward

Producing a building that can function 'on its own' and least impacting the environment was a challenge in itself.

This was achieved by fully integrating into the design, Rainwater Harvesting Systems; Natural Lighting & Energy Efficient Lighting; Energy Efficient Mechanical Ventilation, a Generator Farm and catering for Fuel Efficient Vehicles.

During construction, the project produced Zero Waste, and repurposed in excess of 70% of waste.

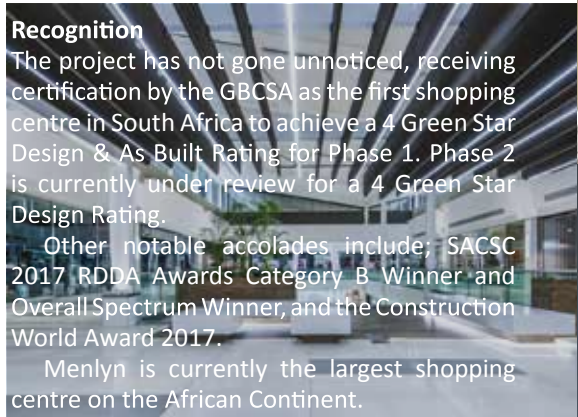
Daily, 80% of operational waste is diverted from landfills thanks to its own recycling facility and implementation of a Waste & Recycling Management Plan.

### Recognition

The project has not gone unnoticed, receiving certification by the GBCSA as the first shopping centre in South Africa to achieve a 4 Green Star Design & As Built Rating for Phase 1. Phase 2 is currently under review for a 4 Green Star Design Rating.

Other notable accolades include; SACSC 2017 RDDA Awards Category B Winner and Overall Spectrum Winner, and the Construction World Award 2017.

Menlyn is currently the largest shopping centre on the African Continent.





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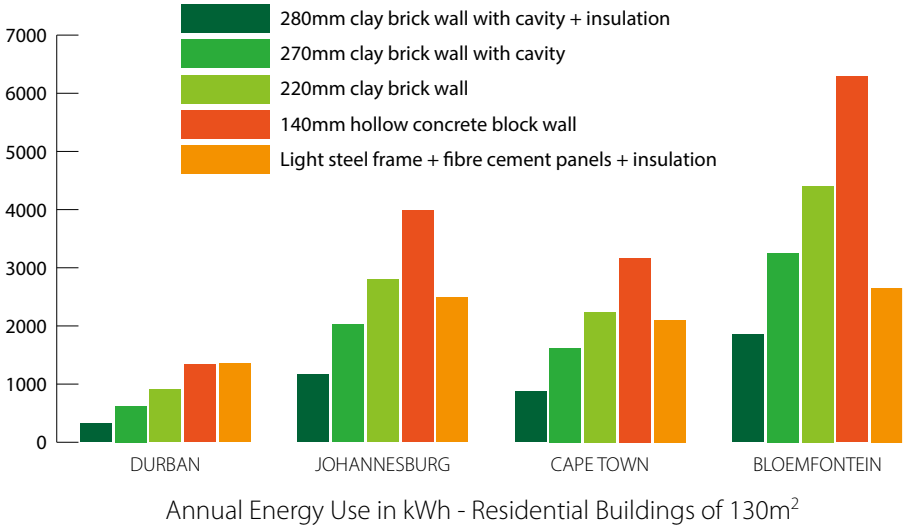
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# The Green Building Handbook South Africa Volume 11 Materials and Technologies

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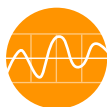
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The Publisher and the Editor allocate a reviewer to an article and then send it to the reviewer who is well acquainted with the topic. Reviewers return an evaluation of the work to the Editor, noting weaknesses or problems along with suggestions for improvement. The Editor notes the reviewer's recommendations and will either publish the article without changes, request that the author amend the article in accordance with recommendations or reject the article but encourage revision and invite resubmission.

The Editor evaluates reviewer submissions and is under no obligation to accept recommendations. The Editor may also add his or her opinions and recommendations to those of the reviewer before passing these back to contributors. Peer reviewed articles may not necessarily have incorporated all recommendations made by the reviewer but are likely to have been amended from the original version.

Alive2green is proud to have embarked on the journey of peer review and now strives to achieve certain objectives in this process which include, but are not limited to:

- Extremely high standards of published material
- Acceptance of handbooks in academic institutions, including as prescribed text books
- Increased publicity and exposure for handbooks in global academic circles
- Increased exposure for contributors and editors within academic, industry and peer-review circles
- Increased quality of learning texts for Alive2green online learning modules which are based on handbook content.
- Relevant and extensive coverage for advertisers within the handbooks and online.



# EDITOR'S NOTE

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Over the years the Green Building Handbook has increased its scope beyond the confines of 'green building' as typically defined in green building rating systems. This is largely due to the recognition that building green, or more accurately, building sustainably, cannot occur only at the scale of an individual building. Ultimately, it is at the human settlement scale, with all of its complexity, that sustainability is required.

Buildings, or more precisely their occupants, are dependent on numerous inputs for its ongoing operation. Generally those inputs occur at a city-scale, and include water, sanitation, and energy. Given the current water shortage in Cape Town it would be amiss of this publication not to respond to this challenge, especially as the

climate change impact projections indicate an increasingly hotter and drier country. Two chapter's present alternative solutions to this crisis, arguing that just as renewable energy promised alternative solutions to energy shortages, the adoption of renewable water as a similar concept offers alternative solutions to the water shortage.

Transport has been a feature of green building rating tools since their inception: a chapter evaluates the pros and cons of the Green Building Council of South Africa's commuting calculator using ten Green Star rated buildings in Gauteng Province, with a focus on mass transport ratings. The evaluation is necessary, among other things, to guide decision makers on the implication of the star ratings on general transport planning.

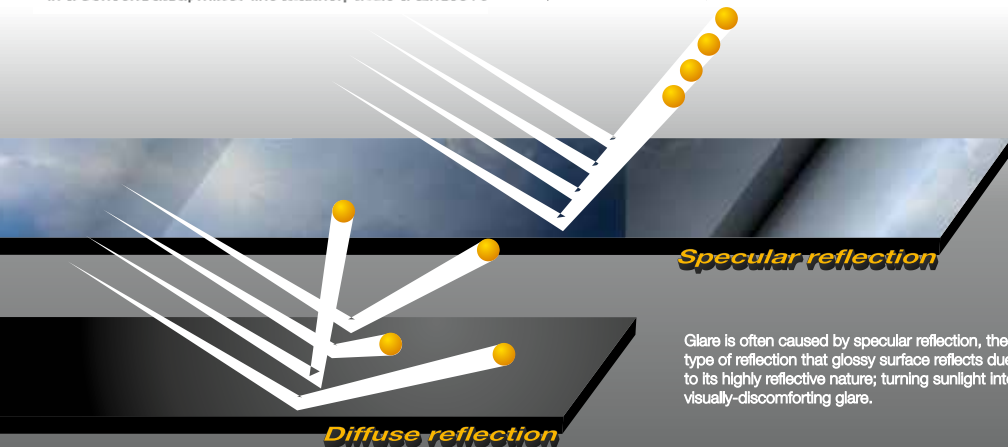


# There is Genius in **MATT-ness**



## How does **MATT** work?

There are two kinds of light reflection - specular reflection and diffuse reflection. A specular reflection occurs when light is reflected in a concentrated, mirror-like manner; while a diffuse reflection, on the other hand, is a scattered and unfocused reflection of light.



Glare is often caused by specular reflection, the type of reflection that glossy surface reflects due to its highly reflective nature; turning sunlight into visually-discomforting glare.

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**BLUESCOPE**

# EDITOR'S NOTE

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Given the climate change projections for South Africa buildings need to be designed to minimise the impact of sun and heat: a chapter quantifies the energy benefits when various solar protection measures are applied to the various facades (east, north, west and south) and roof in all the climatic regions of South Africa.

How buildings are made is critical to their sustainability: two chapters deal with building systems and materials. The first of these introduces climate change projections for different areas of South Africa and determines the implications of these changes for buildings. The second chapter examines the partial substitution of OPC with metakaolin (MK) as a way of reducing energy consumption of cement production and CO<sub>2</sub> emissions into the atmosphere.

The construction of buildings also produce waste: a chapter argues that in line with global trends, the perception in South Africa is also changing to view processed

builders' rubble as a very useful construction material.

Making design decisions around innovative building technologies can often be daunting: a chapter presents a framework for the Decision Support Tool for the selection of innovative building technologies (IBTs) in the delivery of South African social infrastructure aimed at helping users to gain a better understanding of the IBT under review.

Lastly, the development of sustainability science has highlighted the need for a proactive policy response: a chapter evaluates the role and application of Science, Technology and Innovation (STI) in the realisation of sustainable human settlements.

Each of these chapters addresses a component of human settlement formation, and posits alternative strategies and propositions for a more sustainable development paradigm. They should be seriously considered by all human settlement stakeholders.

## Sincerely

*Llewellyn van Wyk*  
Editor

# ACTIVATE ARCHITECTS - CASE STUDY FOR MDA OFFICE REFURB

The MDA office is specifically designed to equip their people with the knowledge, skills and attitude to fulfil their role as future leaders within the MDA organisation, and to give them the workplace to enhance not only their productivity, but also reduce the natural resource depletion on the environment.

The new office boasts various spaces to work privately, collaboratively and interact socially. The building is designed to capture and enhance the essence of the 100-year-old house structure with further intervention in the form of a modern new addition on the site it was founded upon. Activate were the architects for the project and Solid Green were the Green building consultants.

Some key green targets in terms of the project design are:

- 117.4m<sup>2</sup> PV Installation on the new flat roof to be installed with a potential 17.4kWp with an annual yield of 31.571MWh/annum
- Only high frequency ballasts (LED fittings) have been installed with a lighting power density of 1.5W/m<sup>2</sup>
- Rain water harvesting to be installed and reused in the building making the building net zero water. 0.58L/day/m<sup>2</sup> estimated to be used in the building
- Effective energy and water meters installed to ensure the entire building and site consumption is monitored and reported on where irregular occurs



- One of the most efficient air-conditioning and heating systems (VRV) is installed with use of air cooled chillers to ensure no water is wasted.
- The site is to be retrofitted with water saving Xeriscape gardens
- The site is located close to the Gautrain and various bus routes connecting to transport interchanges
- Killarney Mall is situated within 400m of the site with various amenities reducing the need for single occupancy vehicle usage promoting health for all building users
- The parking area allows for cyclist bays, car-pooling and alternative vehicles
- The building is designed to enhance the essence of the 100-year-old house with a modern new addition added

The project is an alteration – modernisation of an existing brick building (old House) and an extension of the office accommodation with the steel and glass structure in 33 West street, Houghton Johannesburg.

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The CSIR's mandate as stipulated in the Scientific Research Council Act (Act 46 of 1988), section 3: "The objects of the CSIR are, through directed and particularly multi-disciplinary research and technological innovation, to foster, in the national interest and in fields, which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act."



Well-functioning infrastructure and an efficient built environment are essential to socio economic development and poverty alleviation. One of the Built Environment's focus area is developing, improving and maintaining the built environment – the economic infrastructure and human settlements by developing key solutions that can be used by all stakeholders. The organisation contributes to sustainable infrastructure development, asset preservation, socio-economic growth and global competitiveness for the built environment.

The fundamental need for socio-economic development, the cornerstone of societal well-being, can be addressed only when people have access to basic services and amenities such as electricity, water, sanitation, proper housing, schools and hospitals. The CSIR's impact is grounded in innovative, relevant and cost-effective research, development and innovation (RD&I), undertaken by teams of committed specialists who enjoy national and international standing. Our RD&I focus is in support of the government's increased focus on infrastructure development and service delivery.

The CSIR's contribution lies in the use of science, engineering and technology to contribute to the development and maintenance of the country's economic infrastructure and the transformation of human settlements. The organisation's main focus areas are the integration of data in decision-support systems for planning and maintaining settlements; improving the efficiency of buildings and developing new building materials and construction methodologies; developing design methods and maintenance procedures for road, port and railway infrastructure; and developing models and methods for more efficient public and freight transport.

A crucial part of the CSIR's contribution is in knowledge dissemination and transfer, and it is in this area that the Green Building Handbook performs a critical role. It is one of the mediums that the CSIR uses to ensure that the knowledge it generates is shared with built environment stakeholders, including clients, public institutions, and built environment professionals.

It is with this background that I endorse and commend this publication and trust that it will prove invaluable in the exercise of your professional duties.

*Kenny Kistan  
Acting Executive Director, CSIR:  
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Peter Kidger is a retired marketing executive for Corobrik and consults for the CBA. He has a long time passion for clay bricks, their investment value in South African architecture, and their basket of natural performance attributes that set this man-made building material apart for advancing beautiful and holistically sustainable, built environments.



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Kirsten is a Waste Economy Analyst at GreenCape - a sector development agency established to unlock the potential of the green economy. Her focus is on maximising opportunities for and overcoming barriers to the waste economy in South Africa. Builders' rubble is currently her primary focus area, working with pavement engineers, crushing and demolition companies, construction companies, industry bodies as well as all levels of government to facilitate the growth of the economy in secondary materials from construction and demolition waste.



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# STEEL ROOFING COMPLEMENTS NATURAL ENVIRONMENT



## Project Background:

Increasingly the developers of modern, sustainable housing estates have been looking at the longevity and performance of construction materials used on site.

Sitari Country Estate near Somerset West is presented as 'the art of country living'. According to the developer, UVEST, 'olive groves, orchards, water features and landscaped gardens are subtly intertwined in a secure environment'. It offers 3150 units of luxury and premium residential apartments, village homes and country homes, including a private school and shopping centre – a large built environment by any standard.

Upmost in the mind of the designers was the impact of the development on nature and inhabitants. From the top, the steel roofs that cover most of the buildings are built to last. Well known premium steel roofing material, Clean COLORBOND® Ultra Matt in AZ200 coating mass was specified by the project team and formed into very popular and 'much-loved' concealed-fix Diamondek by Youngman Roofing.

However, another unique attribute of this product also makes it uber-important for housing developments of this pedigree. According to BlueScope's Regional Manager

for Africa, Arno Hanekom, manufacturers of Clean COLORBOND® : "We conducted extensive testing and benchmarking before recommending Clean COLORBOND® Ultra Matt to the developer, UVEST. Modern pre-painted steel roofing can have a high degree of gloss caused by the specular reflection of the sun's rays off its surface. In an eco-sensitive environment this often causes a problematic glare which is also disturbing to residents. Our Clean COLORBOND® Ultra Matt offers a high-tech and elegant solution to this problem, while ensuring that the same amount of inbound infrared is reflected off the roof and keeping the building as cool inside as with our standard range."

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**Project: Sitari Country Estate**  
**Developer: UVEST Property Group**  
**Architects: BPAS Architecture**

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# Energy Efficient Roofing

When shopping for an energy efficient roof for your home, keep an ear out for key words like “solar reflectance,” “thermal emittance” and “Energy Star rating.” Energy Star certified roofs come in a variety of materials like metal, tile and asphalt shingles, with metal having the best reflectance values of them all. It’s important to note that colour also makes a big difference. For example, lighter roofs can stay more than 10 degrees cooler under the summer sun than darker roofs.

The longer a roof is exposed to the heat of the sun, and the darker its color, the hotter the roof. With conventional roofing material, the heat is absorbed in the sheathing beneath the attic area. Once here, the heat can then travel down into a home’s living spaces. The condition of a home’s insulation will influence the rate this occurs. This is called the heat-soak effect. As a home becomes warmer, there will be more energy demands from the air conditioner. With energy efficient roofing materials, the heat soak effect will be minimized. It decreases the heat passing into a home’s living area. This will decrease the energy demands placed on an air conditioning system.

Energy-efficient roofs benefit from two properties known as emittance and reflectance. Reflectance is how a roofing material reflects the sun’s energy back into the atmosphere. It does not absorb the heat. An energy efficient roof is made from materials that provide superior emittance and reflectance values using cooling materials.

Benefits of Energy Efficient Roofing include

- Lower utility bills
- Longer life expectancy
- Increased home comfort
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Warranties on materials and components are provided on request.

## TECHNICAL SERVICE AND SUPPORT

Safintra technical experts are based at all our branches to support our clients and installers wherever they are.

The Technical Team work closely with professionals and building owners to solve challenging design demands and meet stringent performance requirements.

Our accredited roofing installers are trained to work with our products, and offer warranties on installation (T & C apply).

## BRANCHES:

Johannesburg, Cape Town, Durban, Port Elizabeth, Polokwane, Nelspruit, Bloemfontein. [www.safintra.co.za](http://www.safintra.co.za)

Further branches throughout SADC, Southern and Eastern Africa. [www.safintra.com](http://www.safintra.com)



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The **Saflok**® concealed-fix roof system (available in both 700 and 410 mm cover widths) includes patented Saflok clips which lock down the sheeting to perform in extreme conditions.

The **Newlok**® standing seam profile has distinctive aesthetic appeal and commanding wind hold down performance.

Our exclusive pierced fix profiles include the timeless **Classicorr Corrugated**®, plus the trapezoidal range of **Tufdek IBR**®, **Widedek**®, **Trimflute**® and **Fluteline**®, all with their own unique performance benefits.

**Versatile**® has the appearance of tile but the structural strength of a continuous sheet, which also provides for watertightness and easy installation.



## SAFINTRA SUPPLIES ALL THE COMPONENTS REQUIRED TO MAKE UP A COMPLETE ROOFING SYSTEM

Warranted components ensure the system will perform to its full design life. These include **Fixtite**® Fasteners, **Saftherm**® Insulation, the **AshGrid** roof spacer system for new roofing or over roofing, and a range of clamps for above-roof attachments, plus bespoke flashings and trims and water-management goods.



A member of the



Safintra is a member of Safal Group, the premier roofing company in Africa, and it's largest manufacturer of world class Aluminium-Zinc coated steel.

# Power Tools

Power tools have multiple applications in homes and commercial establishments. Power tools enjoy many advantages over hand tools. In recent years, the demand for power tools has increased considerably.

## **Main advantages of using power tools include :**

- High speed reduces completion time of task
- Effectiveness and can be used to perform several tasks
- Increased efficiency

## **Energy considerations**

Power tools have big appetites. The moment you turn them on, they gobble up more than their fair share of electricity.

## **How much power do my tools need?**

Tools are fueled by amps - to check how much yours need, check the nameplate located on the tool's body or motor housing. Look for information about AMPS and VOLTS.

## **Do I have enough power to draw from?**

Most homes built in the last 40 years or so have 100- to 200-amp service. This should be plenty of power to run a modern household and a shop. Consider having an electrician install a subpanel in your shop so you don't have to share circuits with the house. This allows for shorter wiring, which decreases power loss and heat buildup, and also gives you the option to shut off power to the shop when not in use.

## **How should I size my circuits?**

Start by examining the list you made of your tools' amperage requirements. Keep in mind that electrical codes require a load on a circuit not to exceed 80 percent of its capacity. This means if you want to run a 16-amp table saw, you need a 20-amp circuit. If you ever run two high-power tools at the same time – such as a table saw and dust collector – you need two separate circuits to handle the load.





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Power Tools SA

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# Compaction in the Waste/ Recycling Industry

In the waste handling and recycling industry, compaction plays a big role in reducing the size of waste matter so that, primarily, more of it can be stored or accommodated in the same space. At dumpsites and landfills, waste is compacted even further as a way of extending the lifespan of that area.

Waste is generated everywhere and the need to control how that waste is affecting our environment continues to gather momentum all over. There is waste coming out of our homes, our businesses, institutions of learning, health facilities, industries and just about everywhere else that has people around, including stadiums and parks.

The advantages of using compaction solutions are numerous. Compacted waste means less trips to the landfill are needed. This is a more eco-friendly solution to waste removal – fewer trips to the landfills will reduce transportation costs and the pollution or emissions created from those trips. Also, companies that use trash compactor equipment and promote such use will improve their reputation among consumers as more people these days are adopting 'green' lifestyles. Consumers are more likely to do business with a company that promotes eco-friendly waste management programs.

With more government regulations being enacted to promote eco-friendly solutions and more people demanding businesses run their companies in a more environmentally friendly way, it just makes smart business sense to take advantage of compaction equipment for the disposal of their waste. Companies that adopt 'green' practices including eco-friendly compaction equipment will prosper and gain a competitive edge.



# The value of recycling in South Africa is not worth the effort

There is a huge misconception about the value of recyclable waste and the impact this waste has on the environment.

Recycling in South Africa is governed by financial impact. If there is no monetary benefit why should you be concerned about recycling anyway? Unfortunately the value of recycling in South Africa is generally not worth the effort.

A handful of companies make a financial return on recycling and if the product output is in high demand this recycling becomes beneficial. There are a small number of products that produce high value byproduct, these include: diesel produced from recycling tires, new extrusions produced from aluminium recycling and of course recycled metal products produced from our road signs and barriers stolen by waste-preneures.

The question of how to reduce the strain on landfill sites by quantity reduction of low or no-value items has puzzled many concerned business, building and property owners for years.

In an interview with the owner of Bulkmatech South Africa, Ingo Laufer, the concept of reducing waste to landfill has a simple yet profound solution. Bulkmatech, a company whose foundations are firmly rooted in helping business and property owners convert their operations into green friendly operations, live by the mantra of Reduce, Re-Use, Recycle.

Ingo says that although recycling is not always a feasible solution for many businesses all should do their part by reducing the amounts of waste they send to landfill. "The solution to reducing your landfill contribution



is simple,"he says, "reduce the amount of space the waste occupies."

There are many financial benefits to the type you of waste reduction suggested by Ingo from Bulkmatech, these include: reduce transport costs as fewer trips to the landfill site are required, reduced landfill costs and more compacted waste is disposed of requiring less space at the landfill and there are a number of hygienic benefits like a cleaner work environment on your property. Interestingly enough, Bulkmatech clients also reported less shrinkage as hiding stock in a compacted waste bundle in not east to retrieve.

Even though recycling is not always cost effective there is at least an alternative solution that will help any business producing waste an option to contribute to the future of our country and generations to come.

*Bulkmatech has a creative waste reduction solution for many different environments. Contact Bulkmatech on 0861 782358 or visit their website for more information. [www.bulkmatech.co.za](http://www.bulkmatech.co.za)*





# Windows and doors

**W**indows are complex and interesting elements in the fabric of a home. They let in light and fresh air and offer views that connect interior living spaces with the outdoors. However, windows can be a major source of unwanted heat gain in summer and significant heat loss in winter.

Energy efficient windows make your home more comfortable, dramatically reduce your energy costs and help to create a brighter, cleaner and healthier environment.

Windows can severely impact on the heating and cooling loads of a building. Up to 40% of a home's heating energy can be lost and up to 87% of its heat gained through windows. Improving windows' thermal performance reduces energy costs and greenhouse gas emissions.

## Doors

What makes energy efficient doors different from normal ones? Quite simply, it's what they're made of, the way they fit into and seal your doorframe, and the fact that they are nearly five times more insulating than normal wooden doors.

Distinguishing characteristics of energy efficient doors that make their case for good door insulation:

- They are made from fiberglass or painted steel
- Filled with a core of polyurethane foam
- Usually sealed using a magnetic strip similar to refrigerator doors

If you want to up your game and really go green, you can choose energy efficient doors that contain recycled steel or buy fiberboard doors that are molded from 100% recycled wood fibers

Benefits of energy efficient doors:

- Eliminate drafts – keep warm air in and your family healthy
- Protect your home – special glass coating filters out damaging UV rays from the sun
- Energy efficient doors can help you save up to 15% on your energy bills through effective door insulation

"IS IT POSSIBLE TO BUILD AN ENERGY-EFFICIENT HOUSE THAT STILL OFFERS ME CREATIVE FREEDOM IN TERMS OF DESIGN?"

GEERT VAN DEN OETELAAR  
(M30 Architecten)



## OUR ANSWER: THE REYNAERS ENERGY-EFFICIENT SOLUTIONS



Reynaers' latest aluminium window and door systems meet the high standards for building energy-efficient and even passive houses. In addition to superior insulation values, our low energy systems also offer extremely high performances when it comes to wind and water tightness whilst offering creative freedom in terms of design. Their strength and stability make it possible to integrate large windows offering a maximum entrance of natural light. The Reynaers sustainable solutions will last you a lifetime, responding to your needs for comfortable and sustainable living in South Africa both during extreme winters or hot summers.

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**MagnaBoard®** (Magnesium Oxide Board) provides a total solution for healthy, affordable, durable and energy efficient buildings. MagnaBoard is a technologically advanced building material offering superior performance in every category when compared to traditional products.



MagnaBoard is made from a mineral product, **completely hygienic**, reduces allergic reactions and is conducive to cleaner homes, offices and other environments. It is non-toxic, free of carcinogens, VOC's and contains no silica. The manufacturing process is eco-friendly and the raw material, magnesium oxide is an extremely abundant resource.

## **The product is 100% recyclable.**

Around the home or office it is a winner, being totally **fire resistant, impervious to water, resistant to mould and mildew** and along with its **superior thermal and acoustic insulation** properties make this product a key element in any modern environmental build.



The board is extremely stable and when exposed to dramatic temperature changes will experience minimal expansion and contraction. It has excellent strength characteristics, is easy to install and **will save dramatically on labour costs** shortening the overall duration of projects.

**MagnaBoard®** is distributed by Magnastruct to the Sub-Saharan Africa Region.

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# MagnaBoard®

MagnaBoard (Magnesium Oxide Board) provides a total solution for healthy, affordable, durable and energy efficient buildings.

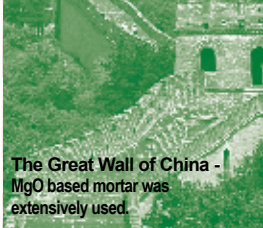
Fire rated; impervious to water; acoustic and thermal advantages; mould and mildew resistant; impervious to insects; a non-toxic board for interior and exterior applications.

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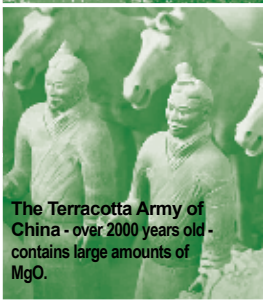
CE certification : AKS0904281501K  
GB8624-2006 (Fireproof Materials) Rating - 'A1'



**Magnesium Oxide through the ages:**



The Great Wall of China - MgO based mortar was extensively used.



The Terracotta Army of China - over 2000 years old - contains large amounts of MgO.



The Pantheon - the 'pozzolana' cement used in many ancient Roman buildings contains large amounts of MgO.



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Taipei 101 (tallest building in the world 2004 - 2010).  
Extensive use made of MgO board on internal and external walls for all 101 floors.

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# We Tread Softly.

Belgotex is proud to receive South Africa's first Custom industrial 6 Green Star rating. This 6 Star certification recognises "World Leadership" at our Pietermaritzburg-based factory for our sustainability practices in all aspects of plant and carpet manufacturing operations. Since the start of our green journey in 1991, we have constantly pushed the limits for operational efficiency,

seeking out ecologically sustainable manufacturing methods and developing eco-friendly products. As the first South African flooring manufacturer to earn the coveted Global GreenTag eco-label certification, we have achieved another significant sustainability milestone. This internationally recognised "Level A" Global GreenTag certification – called

GreenRate™ – maximises our products' eligibility to achieve 100% of the available credit points across all South Africa's Green Building Council (GBCSA) rating tools. The stringent assessment process has equipped us to develop holistically and entrench sustainability across our value chain.





Our Eco-Pillars drive our multi-dimensional, long-term operational plans and they challenge us to ask more of ourselves and less of the planet in all that we do.



Energy

Belgotex has invested over R20 million to date in solar power, resource efficiency and plant upgrades in an active drive to offset CO2 emissions and save energy.



Material

Waste management is high on our agenda, with investments in excess of R5 million that have enabled Belgotex to reduce material waste rates to almost zero.



Water

Embracing change in our traditional manufacturing processes and repurposing harvested rainwater has reduced water consumption by 35 - 45% since 2015.



**Belgotex™**

[www.belgotex.co.za](http://www.belgotex.co.za)

# B.

Suspended : Exposed | Colour: Flint • Floor: Stripped | Colour: Flint

Belgotex is Africa's leading carpet and artificial grass manufacturer. As a soft flooring specialist we design, make and distribute high-quality broadloom and modular carpets with custom solutions available to the commercial market. Our extensive product portfolio includes luxury and specialist vinyls and artificial grass.

We strive to be a world-class African Brand Showcase through the deep connection we share with our people, product and the planet. This vision drives our focus on innovation, quality and sustainable product manufacture to provide certified greener alternatives without compromising on product performance and trend-right design.

Our purpose, founded upon creativity, communication and collaboration, positions us to nurture meaningful connections with our customers and value partners. In this way, we strive to be better every day both as a source of inspiration and the knowledge we hold as experienced manufacturers.



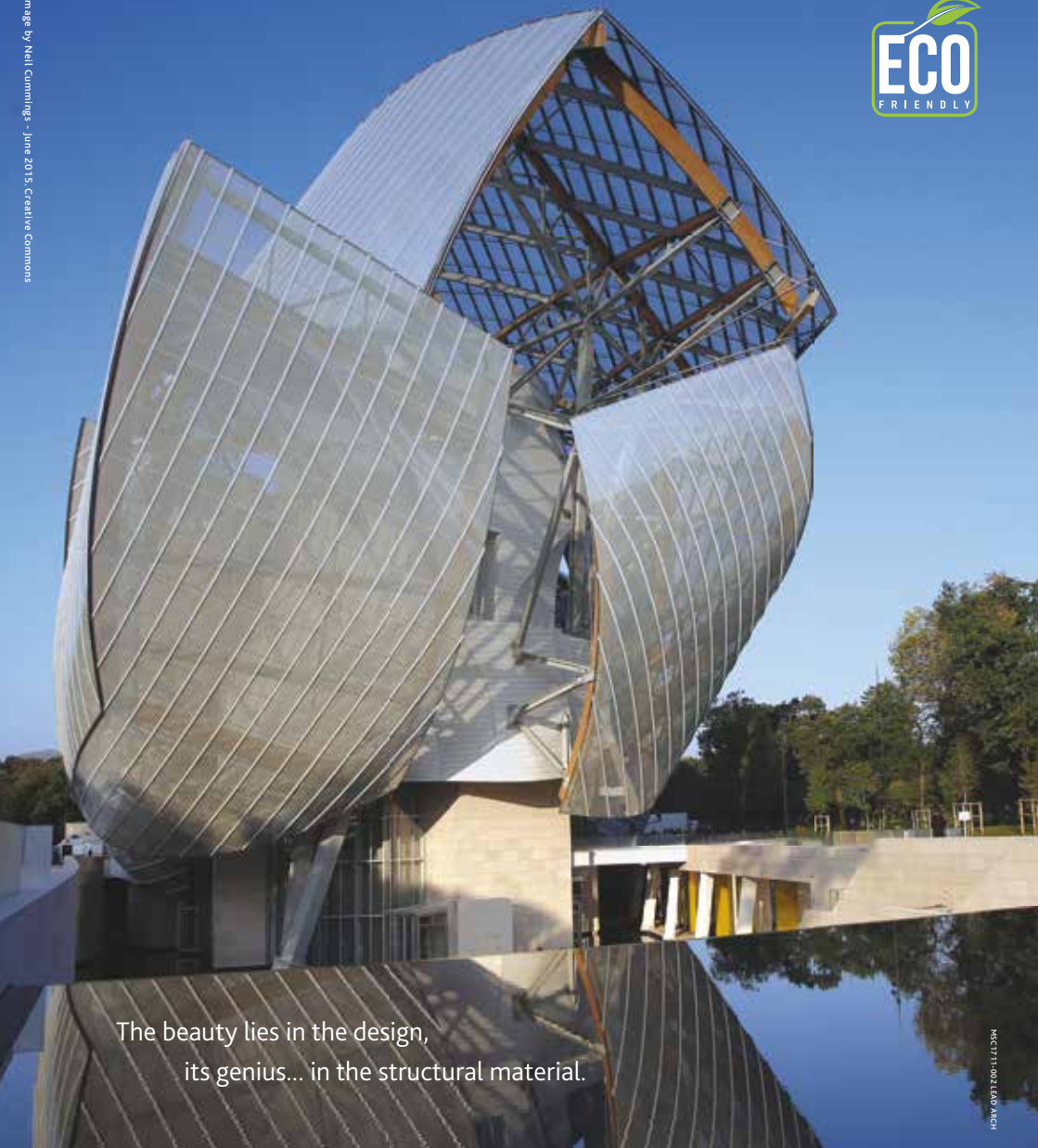
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Our specialist representatives are on call to consult on the unique needs of each flooring installation and ready to recommend the perfect solution for your next project.

# Belgotex™

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The beauty lies in the design,  
its genius... in the structural material.

PHOTO: J. L. LEBLANC

Frank Gehry's architecture is unrivalled in its simple complexity. The Louis Vuitton Foundation in the Bois Du Boulogne, Paris is one of the most remarkable feats of architectural engineering. What made it possible was the use of structural, high-strength duplex stainless steel to support the unique glass sails. As you can see, stainless steel doesn't have to be bright to be brilliant!

**Stainless Steel. It's Simply Brilliant.**

Call 011 883 0119 or see [sassda.co.za](http://sassda.co.za). Your complete stainless information source.



# STAINLESS STEEL IS 'GREENER' THAN YOU THINK!

The sheer brilliance of stainless steel both in appearance and performance is an undeniable fact but it's often not evaluated alongside more accepted 'environmentally friendly' materials, despite its solidly 'green' credentials.

As such, the Southern African Stainless Steel Development Association (Sassda) is passionate about championing the 'green benefits' of stainless steel including the fact that it can easily be recycled to form new products, with no loss in quality. It also lacks the toxic effects of paint to the environment as it doesn't need to be coated or painted in any form, which negates the run off of noxious materials/paint flecks etc. into water, sewerage and storm water systems.

## **A 100-year lifespan**

The concept of Lifecycle Costing is also a key consideration when it comes to assessing the 'green' benefits of stainless steel. Unfortunately, the commonly held misperception is that stainless steel is an expensive material. Yes, it can be more expensive initially but if specifiers, architects and quantity surveyors conduct a full

lifecycle costing exercise (Sassda has developed an easy to use iOS and Android App to assist with these calculations) at the start of a build, the long-term cost benefits of stainless steel become glaringly apparent, as it can survive for 100 years and with far less maintenance.

## **Long lasting buildings**

Local specifiers should therefore be thinking about the lifecycle of the structures they design and the creation of buildings that last for an extended period of time and retain their structural integrity through the use of sustainable materials such as stainless steel.

Against this backdrop, Sassda aims to promote the growth and development of the industry through the provision of key insights as well as information and training to decision makers in the architectural & engineering industry, building & construction sectors, infrastructure, property development and industrial markets, as well as local and national government.

*To find out more go to [www.sassda.co.za](http://www.sassda.co.za)*

# AFRISAM DRIVES ENVIRONMENTAL STEWARDSHIP AND SUSTAINABILITY

AfriSam signalled its seriousness about its environmental stewardship over 20 years ago with the introduction of its first environmental policy in 1994. AfriSam operates this drive towards 'greening' the industry at several different levels simultaneously, making it a leader in environmentally responsible cement and concrete manufacturing in southern Africa.

Significantly, AfriSam was the first cement, aggregate and readymix producer in southern Africa to publish an environmental policy in 1994. Today, the organisation has a comprehensive sustainability roadmap which covers a broad range of focus areas, including waste management, water conservation, biodiversity conservation, emissions reduction and energy management. The company

has established performance indicators that continuously monitor and track compliance to the company's sustainability roadmap targets.

Perhaps one of the least known and exceptional examples of AfriSam's commitment to environmental stewardship is that of the significant archaeological and paleontological finds at its Sterkfontein quarry near the Cradle of Mankind. In this exceptional case, when AfriSam discovered the find it took a business decision to cease all mining operations in the interest of preserving this human heritage site. It has rehabilitated the area and is in the process of donating it to the University of Witwatersrand for further promotion of education.

The current water crisis has featured prominently in headlines recently, but conserving water is not something new for AfriSam. AfriSam has long been implementing measures to reduce water consumption. All operations have water balances in place which allow for optimisation of the resource, and we practice recycling of grey water, which reduces reliance on fresh water.

An important part of sustainability is the need to reduce energy consumption and this is an imperative for AfriSam. AfriSam has set itself stringent targets aimed at reducing energy consumption as well as converting to alternative fuel and alternative energy sources.



**AfriSam**  
Creating Concrete Possibilities



# Chapter 1

---

‘Clay brick wall constructions set both the superior and optimal energy efficiency benchmarks for office and residential building typologies

— Peter Kidger

*You're energy-efficient routes to cost-saving climate control:*

# SAMSUNG & Alliance



We're all aware of South Africa's energy problem, particularly in the hospitality and corporate industries: how to ensure a comfortable environment while at the same time reducing

energy usage and costs. As is well known, two of the highest users of electricity are water heating and climate control. Here's where Samsung and Alliance can provide the answers.



*Samsung Commercial wall mounted indoor unit with bigger capacity*



### Samsung DVM S

For larger corporate or hospitality requirements – as well as upmarket homes – the Samsung DVM S has taken the South African market by storm. With a single outdoor unit supplying up to 64 indoor units – each with their own individual temperature control – the DVM S operates with COPs of up to 4 and more. Samsung's Heat Recovery System uses the hot gas from one indoor unit to heat another unit in the cooler section of the building, ensuring maximum energy savings.

### Samsung Midwall Inverters

Airconditioning remains the most cost-effective way to heat or cool any environment. And the top-quality Samsung commercial Inverter offers an even greater advantage: an advanced digital Inverter technology which saves up to 40% of electricity compared with a conventional airconditioner. This product of bigger capacity is suitable for spaces where it is difficult to install in the ceiling including schools, offices and retail.

### Alliance Midwall Inverters

For quality at a competitive price, Alliance Midwall Inverters are the perfect answer. The Alliance Arctic Inverter is available in 4 models from 9000 to 24 000 Btu/h, and has EER's as low as 3.01 (18 000 Btu/h model). With a sleek curve design with silver trim, heating/cooling and an LED temperature display, the Arctic offers great value for money.



*Alliance Arctic Inverter*

### Alliance Heat Pumps

With water heating accounting for up to 50% of electrical usage, Alliance Heat Pumps provide the ideal 'green' answer. By extracting ambient heat from the atmosphere, Alliance Heat Pumps cut water heating costs by up to two-thirds and more. Domestic units heat from 100 to 500 litres of water, while Alliance Commercial units of up to 82 kW comfortably heat thousands of litres of water per hour.



*Commercial unit*



*Combo unit*

*For more information on Samsung and Alliance products, please contact Fourways Airconditioning.*



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## Introduction:

Both high mass masonry and low mass alternate building technology wall construction types, and their different combinations of thermal mass and resistance, satisfy the minimum 'Deemed to Satisfy' requirements of SANS 10400 Part XA Building Regulations and the SANS 204:2011 Energy Efficiency in Buildings Standards (prescriptive and voluntary).

This Chapter reviews the findings of the University of Pretoria Thermal Modelling Study (TPS), April 2015 (1) in respect of double skin clay brick alternates (un-insulated and insulated) and insulated lightweight walled constructions (LSFB Fibre Board specified to SANS 517 and Timber Frame Fibre Board specified to SANS 10082), and the correlation of these findings with those of both empirical (4 and 5) and thermal modelling research (6, 7, 8 and 9), to provide specifying Professionals answers as to which of the frequently used wall construction methods are indeed the 'more' and 'most' energy efficient for dealing with the unique challenges of South Africa's dynamic external environments.

This information is considered particularly relevant to specifying Professionals faced with the scenario where operational energy usage over a building's life span dwarfs its embodied energy (embodied energy was found to be less than 10% of the total energy consumed by residential over a 50 year lifecycle no matter the wall construction type assessed, (Page 49, The Energetics LCA of Brick Products, February 2010 – 'Final Report after Critical Review' (9)). Within the framework of the 'Deemed to Satisfy' Building Regulations and Energy Efficiency Standards the more thermally efficient building envelope specifications present a significant opportunity to minimise heating and cooling energy impacts and thus the total energy consumed by buildings over their lifecycle.

It is a purpose of the Chapter therefore, to place specifying Professionals intent on applying 'Deemed to Satisfy' wall constructions in their designs, in an informed position to that

wall construction type with the best capability of delivering the lowest heating and cooling energy usage in any one climatic zone for three building/occupancy types and, in the process, facilitate lowest heating and cooling greenhouse gas (GHG) emissions over the building's lifecycle.

## 2. Wall construction compliance in SANS 10400 Part XA Building Regulations and SANS 204:2011 Energy Efficiency in Building Standards:

### 2.1 'Deemed to Satisfy' prescriptive requirements for walls in SANS 10400 Part XA and SANS 204:2011:

The SANS 10400 Part XA Building Regulations and SANS 204 Energy Efficiency in Building Standards for non-masonry buildings set minimum levels of resistance (R-values) for masonry and non-masonry wall constructions to comply.

- Masonry walls require a minimum wall R-value of R0.35 for each of the six major climatic zones.
- Alternate Building Technology lightweight wall constructions, such as Light Steel Frame (LSF) specified to SANS517 and Timber Frame specified to SANS 10082:2007, require higher minimum wall R-values of R2.2 for Climatic Zones 1, 3, 4 and 6 and R1.9 for Climatic Zones 2 and 5.

In the case of masonry walling, a minimum wall R-value R0.35 relates to 140mm 'through the wall' concrete block wall construction.

220mm Solid Double Brick walls typically have a nominal wall R-value of R0.45 and a 270mm Cavity Brick, a nominal wall R-value of R0.60: both exceeding the minimum prescriptive wall R-value (R0.35) for masonry buildings.

### 2.2 'Voluntary' requirements for masonry walls in SANS 204:2011 Energy Efficiency in Building Standards:

The SANS 204:2011 Standard for masonry building (voluntary) contrasts with the prescriptive SANS 204 Standards for non-masonry buildings in that it recognises the findings of both Wentzel J.D., Page-Shipp R.J., and Venter J.A., (1981), The Prediction of the Thermal Performance of Buildings by the CR-Method (2) and the empirical studies at the University of Newcastle (Australia) (3) where the insulation R-value was found not to be the all-important thermal property of a walling material.

SANS 204 for masonry walled buildings sets 'Deemed to Satisfy' 'CR Product' values for different occupancy buildings in each of the six major climatic zones.

A CR Product value represents the time constant property (hours) of a composite element, being the arithmetical product of:

The total Thermal Capacity where:

- $(C\text{-value} - \text{kJ/m}^2\text{.K})$  where total C-value is the sum of the component C-values of individual component layers in a composite element including the airspace, and
- Total Resistance (R-value -  $\text{m}^2 \text{K/W}$ ) derived from the masonry walls themselves, the air between the brick skins and any added insulation appropriate for the different major climatic zones.

Table 1 below sets out the 'Deemed to Satisfy' CR Product values (in hours) masonry

Occupancy group	Climatic zone					
	1	2	3	4	5	6
Residential E1-3,H1-5	100	80	80	100	60	90
Office & Institutional A1-4,C1-2,B1-3,G1	80	80	100	100	80	80
Retail D1-4, F1-3,J1-3	80	80	120	80	60	100
Unclassified A5, J4	NR	NR	NR	NR	NR	NR
NOTE NR = No requirement						

**Table 1 – Minimum Thermal Capacity & Resistance CR Product, in hours, for external masonry walling**

walls require for compliance in the different occupancy building groups.

### 2.2.1 CR Products—Composite Masonry Walls—Residential Buildings:

To achieve the required wall CR Product for Residential buildings, adding insulation R0.5 in the cavity between the brick skins provides a CR Product of 90 facilitating compliance for Climatic Zones 2(80), 3(80) & 6(90).

Including insulation R1.0 in the cavity provides a CR Product of 130, this in excess of the minimum CR Product of 100 requirements for Climatic Zones 1 & 4.

Un-insulated Cavity Brick has a CR Product of 60 and therefore no insulation is required in the cavity for compliance in Climatic Zone 5.

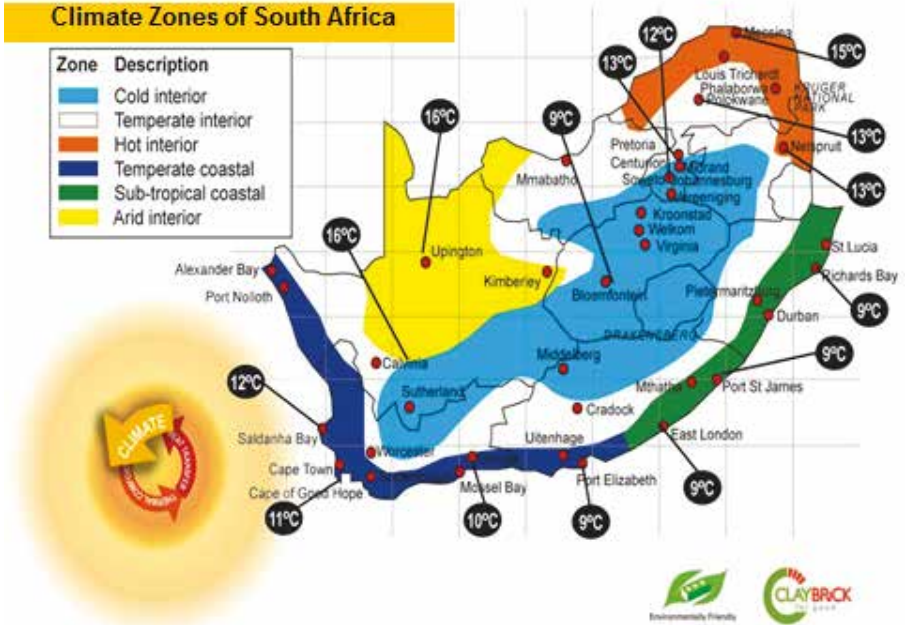
### 2.2.2 CR Products—Composite Masonry Walls—Offices & Institutional Buildings:

In the case of Office and Institutional buildings, including additional insulation R0.5 between the brick skins provides a CR Product of 90 facilitating compliance for Climatic Zones 1, 2, 5 & 6 (80).

Including insulation R1.0 facilitates a CR Product of 130 effecting compliance for Climatic Zones 3 & 4 (100).

### 3. South Africa's Six Major Climatic Zones:

- Zone 1 - Cold Interior
- Zone 2 - Temperate Interior
- Zone 3 - Hot Interior



- Zone 4 - Temperate Coastal
- Zone 5 - Sub-Tropical Coastal
- Zone 6 - Arid Interior

Average annual diurnal temperature swings ranging between 9°C and 16°C are highlighted in the black circles.

“Thermal mass is recognised as being useful where diurnal temperature ranges between 7°C and 10°C and most appropriate where it exceeds 10°C” (Chris Reardon 2013, page 179, Chapter - Passive design, Thermal mass, Your Home (11)).

With much of South Africa being a semi-arid climate at relatively high altitude with large diurnal temperature fluctuations through the seasons, and “where high mass construction with insulation is ideal for maintaining thermal comfort” (Chris Reardon 2013, page 182 (11)), it might be considered fortuitous that South African building construction typically is a heavy mass (high

thermal capacity) construction. Research findings certainly suggest so.

#### 4. Identifying the ‘More’ and ‘Most’ Thermally Competent Wall Construction Types:

To identify which of the high and low mass wall construction types in compliance with SANS 10400 Part XA and SANS 204:2011 are the more and most thermally competent for delivering lowest energy usage, the findings of the 2015 University of Pretoria thermal modelling study (TPS), ‘A Thermal Performance Comparison Between Six Wall Construction Methods Frequently Used in South Africa’, Department of Architecture, University of Pretoria, (Vosloo P., Harris H., Holm D., van Rooyen N., Rice G., April 2015) [1], (in respect of the heating and cooling energy usage of three building typologies located in South Africa’s six major climatic zones), is used. The findings may be considered to provide a realistic and

accurate picture given that they present as reasonably comparable or reconcilable with typical energy usages of the different building typologies used in the study.

Importantly also, the TPS's findings correlate closely with those of Empirical research at the University of Newcastle, Australia, Priority Research Centre for Energy, into the comparative thermal performance of building modules comprising different Australian wall construction types (4 & 5), as well as four thermal modelling studies (three South African that used ASHRAE Standard 140 compliant modelling software (6, 7 & 8), and one Australian used as input to the Energetics Full LCA – February 2010/REF: J/N 107884) (9)).

## **5. The University of Pretoria TPS in respect of the Comparative Thermal Performance of Frequently Used SA Wall Construction Types:**

### **5.1 Modelling considerations:**

The University of Pretoria TPS (1) modelled frequently used wall construction types in compliance with SANS 10400 Part XA Building Regulations and SANS 204:2011 Standards for both non-masonry and masonry buildings. The modelling was applied to three building typologies:

- A 2000m<sup>2</sup> day-time occupancy Office/Institutional type building,
- A 40m<sup>2</sup> Low Cost House and
- A 130m<sup>2</sup> Standard House

The exterior wall constructions and the corresponding internal walling were the only variables.

Floor, roof, windows, fenestration type, doors, and occupancy patterns of all permutations were kept constant to yield comparable results.

An eave of 715mm was provided. A sill height of 1.2m was provided for north facing windows and 1.5m for south facing windows. Window sizes, as determined by SANS 10400 Part O for ventilation and lighting were

applied, i.e. not less than 10% of the net floor areas of rooms which are served are glazed.

## **5.2 Findings by Building Occupancy and Typology:**

### **5.2.1 Gross annual heating and cooling energy usage of a 2000m<sup>2</sup> Office/Institutional day-time (12 hours) occupancy building:**

As reflected in Table 2 the wall constructions for facilitating optimal and superior energy efficiencies for a 2000 m<sup>2</sup> office buildings across all six major climatic zones are:

#### **Optimal Energy Efficiency**

220mm Solid Double Brick wall construction and 270mm Cavity Brick for the Southern Cape condensation environ (Zone 4), rank as the 'most' energy efficient wall constructions, consistently delivering the lowest heating and cooling energy usage in each of the climatic zones and overall.

#### **Superior Energy Efficiency**

270mm Cavity Brick ranks second most energy efficient in each of the climatic zones and overall, just 3.4% less energy efficient than 220mm Solid Double Brick.

Insulated lightweight walled construction, Timber Frame to SANS 10082 and LSF to SANS 517, used the 'more' to 'most' heating and cooling energy respectively.

LSFB lightweight wall construction, the worst performer, consumed 23.5% more heating and cooling energy on average than the 220mm Solid Double Brick and 19.4% more than 270mm Cavity Brick.

As shown in Table 2 insulated lightweight wall constructions show up as particularly poor performers in climatic zones 1, 2, 4 and 5. Compared to 220mm Solid Double Brick, LSF used:

- 34.9% more energy in Zone 1,
- 41.2% more energy in Zone 2,
- 48.0% more energy in Zone 4
- 28.6% more energy in Zone 5.

Page 22, Table 5, of the University of Pretoria TPS (1) reveals the poor performance of the high R-value insulated lightweight wall constructions in Climatic Zones 1, 2, 4 and 5 being consequent to their substantially higher 'cooling' energy usage.

This greater 'cooling' energy usage of high R-value lightweight walls relative to the high thermal mass low R-value brick alternates presents Thermal Mass and the Thermal Capacity (C) it provides and not Resistance (R) as the key thermal performance property for advancing energy efficiency in day-time (12 hour) occupancy office/institutional type buildings.

### 5.2.2 Gross annual heating and cooling energy usage of an all-day (24 hour) occupancy 40m<sup>2</sup> house

As reflected in Table 3, the wall constructions facilitating optimal and superior energy efficiencies for a 40m<sup>2</sup> house across all six major climatic zones are:

### Optimal Energy Efficiencies

280mm Insulated Cavity Brick wall construction is the 'most' energy efficient wall construction by far, consistently delivering the lowest heating and cooling energy usage in each of the climatic zones and overall.

As shown in Table 3, the 40m<sup>2</sup> LSF house, compared to the high thermal mass 280mm Insulated Cavity Brick house, used on average 162.4% more energy:

- 90.5% more energy in Climatic Zone 1
- 185.5% more energy in Climatic Zone 2
- 56650.0% more energy in Climatic Zone 3
- 298.2% more energy in Climatic Zone 4
- 179.4% more energy in Climatic Zone 5
- 65.1 % more energy in Climatic Zone 6
- Superior Energy Efficiency

270mm Cavity Brick ranks second most energy efficient overall this defining its superior status. Relative to 270mm Cavity Brick, LSF to SANS 517 used 26.6%'more' heating and cooling energy and Timber Frame to SANS 10082, some 19.6% more.

Wall Types		Climatic Zone						Gross Average Energy	Energy Efficiency Ranking
		2	3	4	5	6	Six Major Climatic Zones		
1	Bloemfontein	Pretoria	Musina	Cape Town	Durban	Upington			
1	220mm Solid Double Brick	51088	82892	222937	67032	140756	190548	125876	1
2	270mm Cavity (50mm) Brick no insulation	52630	87268	228858	71218	148191	192934	130183	2
3	280mm Cavity (50mm) Brick with insulation	56178	93772	236063	78817	158572	197806	136868	3
4	Timber Frame to SANS 10082	76207	113005	245870	97846	177095	206635	152776	4
5	Light Steel Frame to SANS 517	68921	117083	250258	105389	180980	209769	155400	5
	LSF to SANS 517 is more/less energy efficient than 220mm Solid Double Brick	34.9%	41.2%	9.1%	57.2%	28.6%	10.1%	23.5%	
	LSF to SANS 517 is more/less energy efficient than 270mm Cavity Brick	30.9%	34.2%	9.4%	48.0%	22.1%	8.7%	19.4%	

**Table 2 - Gross annual heating and cooling energy for 2000m<sup>2</sup> Office Building in each climate zone expressed in kWh**

Wall Types	Climatic Zone						Six Major Climatic Zones	Six Major Climatic Zones	Energy Efficiency Ranking
	2	3	4	5	6				
1 Bloemfontein	Pretoria	Musina	Cape Town	Durban	Upington				
220mm Solid Double Brick	1464	1055	1282	734	590	2428	1259	5	
2 270mm Cavity (50mm) Brick with No Insulation	1009	725	887	479	454	1904	910	2	
3 280mm Cavity (50mm) Brick with Insulation	496	379	2	218	296	1244	439	1	
4 Timber Frame to SANS 10082	1012	1066	853	862	786	1953	1089	3	
5 Light Steel Frame to SANS 517	945	1082	1135	868	827	2054	1152	4	
LSF to SANS 517 is more/less energy efficient than 280mm Insulated Cavity Brick	90.5%	185.5%	56650.0%	298.2%	179.4%	65.1%	162.4%		
LSF to SANS 517 is more/less energy efficient than 270mm Cavity Brick	6.3%	49.2%	27.9%	81.2%	82.1%	7.9%	26.6%		

Table 3 - Gross annual heating and cooling energy for 40m<sup>2</sup> house in each climate zone expressed in kWh



270mm Cavity Brick was more energy efficient than LSF in 5 of the 6 climatic zones. LSF used:

- 49.2% more energy in Zone 2
- 27.9% more energy in Zone 3
- 81.2% more energy in Zone 4,
- 82.1% more energy in Zone 5
- 7.9 % more energy in Zone 6.

LSF incurred 6.3% less energy usage in Zone 1.

As shown in Table 3, this higher energy usage of 270mm Cavity Brick was more than reversed with insulation (R1.0) applied between the brick skins, the LSF house (R2.2) using 90.5% more energy than the 280mm Insulated Cavity Brick house.

### 5.2.3 Gross annual heating and cooling energy usage of an all-day (24 hours) occupancy 130m<sup>2</sup> house

As reflected in Table 4, the wall constructions facilitating optimal and superior energy efficiencies for a 130m<sup>2</sup> house across all six major climatic zones, are:

#### Optimal Energy Efficiencies

280mm Insulated Cavity Brick wall construction is the 'most' energy efficient wall construction by far, consistently delivering the lowest heating and cooling energy usage in each of the climatic zones and overall.

As shown in Table 4, the 130m<sup>2</sup> LSF house to SANS 517, compared to the high thermal mass 280mm Insulated Cavity Brick house, used on average 111.4% more energy:

- 42.9% more energy in Climatic Zone 1.
- 114.1% more energy in Climatic Zone 2,
- 2564.4% more energy in Climatic Zone 3,
- 141.3% more energy in Climatic Zone 4,
- 327.7% more energy in Climatic Zone 5,
- 75.4% more energy in Climatic Zone 6.
- Superior Energy Efficiency

270mm Cavity Brick ranks second most energy efficient overall this defining its superior status. Relative to 270mm Cavity Brick, LSF to SANS 517

used 21.6% 'more' energy and Timber Frame to SANS 10082, some 25.2% more.

270mm Cavity Brick was more energy efficient than Timber Frame and LSF in five of the six climatic zones. LSF used:

- 23.2% more energy in Zone 2
- 1437.2% more energy in Zone 3
- 30.0% more energy in Zone 4
- 119.4% more energy in Zone 5
- 6.2% more energy in Zone 6

Relative to 270mm Cavity Brick, LSF achieved 18.5% less energy usage in Zone 1. As shown in Table 4, this higher energy usage by 270mm Cavity Brick in Zone 1 was more than reversed with insulation (R1.0) applied between the brick skins, the LSF house (R2.2) using 42.9% more energy than the 280mm Insulated Cavity Brick house.

### 6. Summation of research findings:

The findings show that when it comes to advancing energy efficiency conventional clay brick wall constructions: 220mm Solid Double Brick and 270mm Cavity Brick, supplemented where appropriate with insulation, provide all the necessary options for achieving comparatively superior and optimal energy efficiency outcomes in both day-time occupancy (12 hours) and all-day occupancy (24 hour) buildings in all six major climatic zones.

Contrasting with this LSF and Timber Frame insulated lightweight walls present a significant thermal efficiency compromise to the 'more' and 'most' energy efficient high thermal mass masonry wall constructions in all three building typologies modelled.

#### 6.1 High 'C' combined with low 'R' for day-time (12 hour) occupancy office buildings:

220mm Solid Double Brick and 270mm Cavity Brick (as applied in the Southern Cape condensation environ) wall constructions, by virtue of their propensity to absorb a large quantity of heat energy for a small rise in temperature and thermal lag of 5 to 7 hours,

Wall Types	Climatic Zone						Six Major Climatic Zones	Six Major Climatic Zones	Energy Efficiency Ranking
	1	2	3	4	5	6			
Bloemfontein		Pretoria	Musina	Cape Town	Durban	Uppington			
1 220mm Solid Double Brick	4405	2797	787	2242	909	4762	2650	5	
2 270mm Cavity (50mm) Brick No insulation	3251	2023	78	1618	619	3662	1879	2	
3 280mm Cavity (50mm) Brick with insulation	1855	1164	45	872	322	2228	1081	1	
4 Timber Frame to SANS 10082	2902	2537	1102	2152	1332	4085	2352	4	
5 Light Steel Frame to SANS 517	2650	2492	1199	2104	1358	3908	2285	3	
LSF to SANS 517 is more/less energy efficient than 280mm Insulated Cavity Brick	42.9%	114.1%	2654.4%	141.3%	321.7%	75.4%	111.4%		
LSF to SANS 517 is more/less energy efficient than 270mm Cavity Brick	18.4%	23.2%	1437.2%	30.0%	119.4%	6.1%	21.6%		

**Table 4 - Gross annual heating and cooling energy for 130 m<sup>2</sup> house in each climate zone expressed in kWh**

present as the optimal and superior walling systems for day-time (12 hour) occupancy office/institutional type buildings.

Applying insulation in the cavity of clay brick walls to advance energy efficiency over the insulated lightweight wall constructions is an unnecessary cost.

Thermal lag of approximately 5 to 7 hours determines that the sun's heat passing through the wall only impacts on the inside spaces after the hottest parts of summer days have passed. Contrasting with this, the sun's heat passing through insulated lightweight walls impacts on inside spaces within 1 to 2 hours (Page A.W; Moghtaderi B; Sugo H.O; Hands S; 2009 (3)), this well ahead of the hottest part of a summer's day. The high R-value insulated lightweight walls then trap the heat inside, the heat flux on the inside coinciding with the hottest parts of day outside, resulting in the highest cooling energy usage to maintain thermal comfort conditions of air-conditioned lightweight walled buildings.

In the case of the institutional buildings such as school classrooms, which rely on natural ventilation rather than air-conditioning to manage internal thermal comfort during day-time hours, the 'hot-box' effect associated with insulated lightweight walled LSF classrooms during summer days understandably presents the most challenging teaching and learning environments.

## **6.2 High 'C' combined with medium/high 'R' for all-day (24 hour) occupancy houses:**

270mm Cavity Brick wall construction presents as the 'generally superior energy efficiency benchmark'. Diurnal temperature swings, as found in climatic zones subjected to colder winter periods, determines that insulation be added between the brick skins to limit heat loss and extend thermal comfort conditions in those climates.

280mm Insulated Cavity Brick, by virtue of its higher CR Product to that of the other wall constructions studied, defines the 'optimal energy efficiency bench mark' for 40m<sup>2</sup> and

130 m<sup>2</sup> houses. That clay brick construction does so with insulation of a somewhat lower R-value than applied in light-weight walled LSF and Timber Frame constructions ensures that best energy savings/ pay-back for the cost of insulation applied, is the preserve of clay brick construction. This was confirmed in studies 6, 7 & 8.

## **7. Design interventions for further capitalising on the thermal properties of high thermal mass wall constructions:**

### **7.1 Window size optimization:**

Window size optimisation and resultant thermal performance benefits (or otherwise) were not factored in the University of Pretoria TPS.

A sensitivity study into the effects of window size optimisation found that: "the optimisation of the North elevation fenestration area as applied in Climate Zone 1 i.e. the Highveld Region, demonstrates that the performance of un-insulated masonry solutions can be enhanced (energy usage reduced) by the optimisation of window area and the positioning of sill heights in relation to the shading provided. This makes buildings with standard RSA masonry walling less likely to overheat with increased window sizes. The same cannot be said of light-weight walling systems which demonstrate a significant over-heating if window areas are increased" (Chapter 3, Pages 11&12, sub-paragraph 3.3.2.12 of the TPS (1)).

As shown in Table 1, page 12, sub-paragraph 3.3.2.12, of the TPS (1), window size optimisation affords a:

- 10% reduction in the energy consumed by the 220mm Solid Double Brick walled house
- 5% reduction in the case of the 270mm Cavity Brick walled house.
- Conversely, LSF and Timber Frame increased energy usage by 51% and 48%, respectively.
- Consequent to this, the TPS noted that: "modelling of a standardised window rather than an optimised window size and positioning in the wall significantly favoured the light-weight systems as the over-heating

impact and additional cooling requirement were not included in the non-masonry walling modelling results”.

Optimising window sizes presents as a pragmatic way for ing Professionals to further advance the energy efficiency of the 24 hour occupancy 220mm Solid Double Brick and 270mm Cavity Brick houses relative to both LSF to SANS 517 and Timber Frame to SANS 10082.

## 7.2 Passive solar design interventions:

In addition to this, specifying Professionals can positively apply Passive Solar Design interventions to take the superior thermal performance of SANS 10400 Part XA and SANS 204 compliant clay brick wall constructions to another level. ‘For best effect, thermal mass must be integrated with sound passive design techniques’ (Chris Reardon 2013, page 178, Passive Design Thermal Mass, Your Home (11)).

Having appropriate areas of glazing facing appropriate directions with appropriate levels of shading, ventilation, insulation and thermal mass are key:

- Orientating the house to the North to optimise the opportunity to use the sun’s free energy to best effect
- Window placement and ventilation to enable the prevailing breezes to pass over the thermal mass, drawing out all the stored energy on summer evenings
- Shading through eaves supplemented with retractable shading/blinds designed to protect the thermal mass from excess summer sun, yet facilitate exposure of that thermal mass to the sun’s radiant heat in winter
- Placement of thermal mass internally to absorb heat during the day from direct sunlight or from radiant heaters for release back into the home throughout the winter nights
- Insulation of windows and door openings to prevent heat loss to the cold winter air

It is the correct use of thermal mass that ‘enables the moderation of internal temperatures by averaging out diurnal (day-night) extremes thereby increasing comfort for longer periods and reducing energy costs’ (Chris Reardon 2013, page 178, Passive Design Thermal Mass, Your Home (11)).

## References:

- Vosloo P, Harris H., Holm D., van Rooyen N., Rice G., (April 2015), A Thermal Performance Comparison Between Six Wall Construction Methods Frequently Used in South Africa, Department of Architecture, University of Pretoria (1)
- Wentzel J.D., Page-Shipp R.J., and Venter J.A., (1981), The Prediction of the Thermal Performance of Buildings by the CR-Method, National Building Research Institute, CSIR South Africa (2)
- Page A.W., Moghtaderi B; Sugo H. O; Hands S; (2009), A Study of the Influence of the Wall R-value on the Thermal Characteristics of Australian Housing, University of Newcastle, Australia (3)
- Page A.W; Moghtaderi B., Alterman D., Hands S., (2012), A Study of the Thermal Performance of Australian Housing, Priority Research Centre for Energy, Priority Research Centre for Energy, The University of Newcastle, Australia, [www.thinkbrick.com.au](http://www.thinkbrick.com.au) (4)
- Energy Efficiency and the Environment - The case for Clay Brick – Edition 4, [www.thinkbrick.com.au](http://www.thinkbrick.com.au) (5)
- Braune M., Gray W., Oxtoby S., (2009/2010), 40m<sup>2</sup> Low Cost Housing Energy Modelling Project, WSP Green by Design (6)
- Harris H., (2009), Thermal Modelling of a 132m<sup>2</sup> CSIR house using Visual DOE software, Structattherm Projects (7)
- Braune M., (2010), External Wall Types Assessment for 130m<sup>2</sup> Residence, WSP Green by Design (8)
- Energetics (Pty) Ltd, (February 2010), LCA of Brick Products, Life Cycle Assessment Report, Final Report after Critical Review, for Think Brick Australia - <http://www.thinkbrick.com.au> (9)
- Johannsen A., (2012), A Parametric Energy Modelling of Middle Income 130m<sup>2</sup> Residences for South African Conditions in Six Climatic Regions in South Africa, with Four Walling Systems (10)
- Reardon, C., McGee, C., and Milne, G., 2013, Pages 178 to 187, Chapter - Passive Design Thermal Mass, Your Home – Australia’s Guide to environmentally sustainable homes, [www.environmentaldesignguide.com.au](http://www.environmentaldesignguide.com.au) (11)



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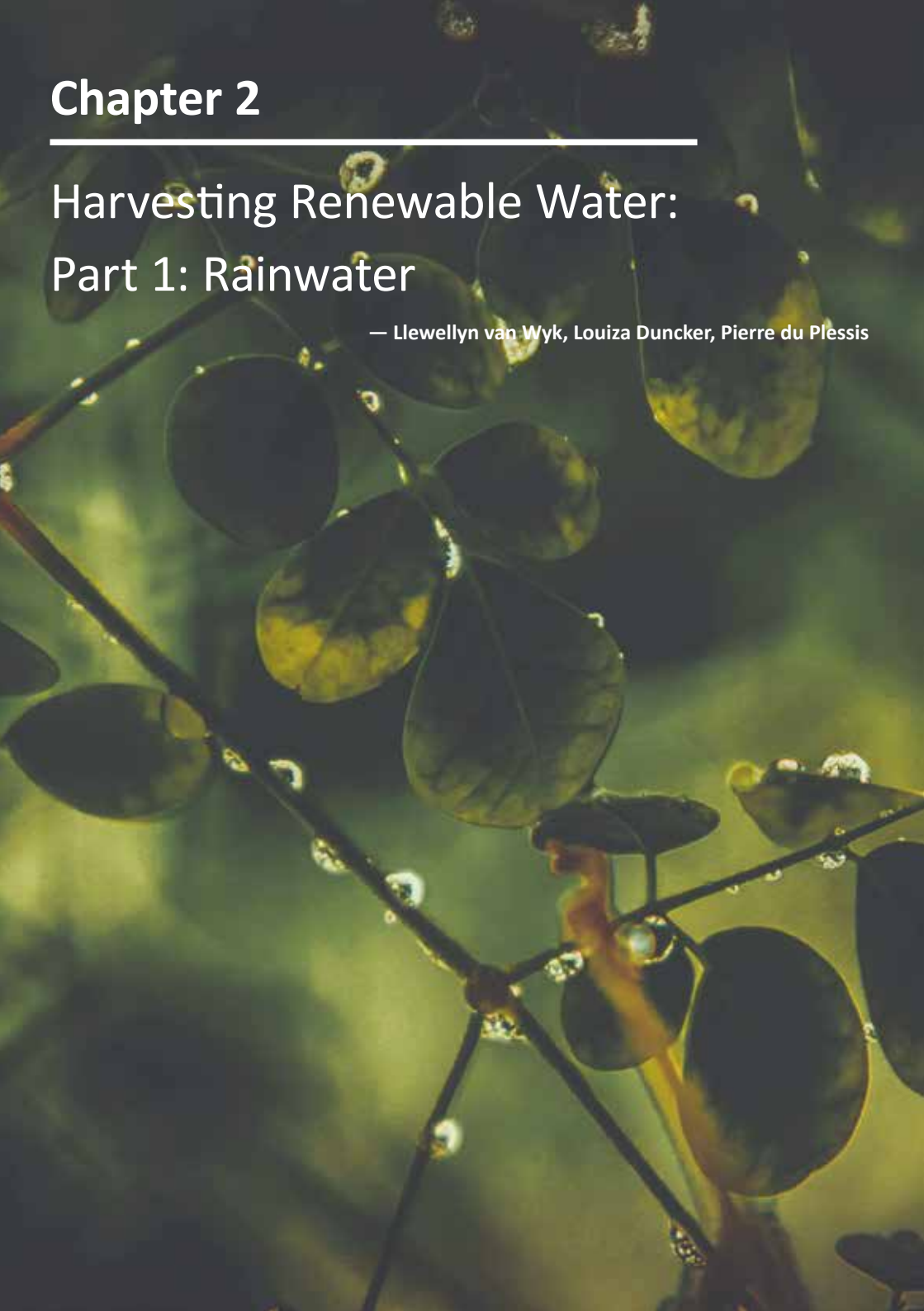
E-Design by Swiss Architect Beat Pfenniger  
\*Agrément South Africa is currently certifying the CITRA building technology.  
The certification process is expected to be completed in the first half of 2018.

# Chapter 2

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## Harvesting Renewable Water: Part 1: Rainwater

— Llewellyn van Wyk, Louiza Duncker, Pierre du Plessis



## Introduction

As noted on the Cape Town City website, the city is a water scarce region and is experiencing a very serious drought as a result of insufficient rainfall. In an effort to conserve water the City introduced Level 4b water restrictions with effect from 1 July 2017: this entails a ban on all use of municipal drinking-water for outside and non-essential purposes. The City has also called on consumers to restrict their water use to less than 87 litres per person per day.

Given that under most of the climate change scenarios South Africa is likely to become hotter and drier, the water scarcity experienced currently by the City of Cape Town is a harbinger of future water trends in South African cities, and thus provides a timely case study to explore other water conservation management options.

This chapter explores alternative and supplementary water conservation management options using Cape Town as a case study to test the options with a view to determining what impact it may have on water yield and demand.

## Integrated Water Resource Planning

Securing water resources is an imperative to the sustainability of any city. To this end, an integrated water resource plan aims to integrate all water-related initiatives that foster water conservation (COCT 2013). The City of Cape Town committed itself in 2013 to save approximately 90 million l/annum by 2016/17 (COCT 2013). A commitment in the 2007 water conservation and water demand management (WCWDM) strategy included reducing the growth in potable water demand to no more than 1% p.a. for the next 10 years, but the 2013 review found that this goal was not realistic and was therefore adjusted to 2% p.a. (COCT 2013).

The total water demand for the metropolitan areas amounts to approximately 904.2 Ml/day (COCT 2013). Analysis done for the 2011/12 consumption figures (Figure 1) indicates that 47.8% of the overall demand is generated by the residential sector (435 Ml/d), while between 25% and 30% (between 108 and 130,5 Ml/d) of that demand is utilised for gardening purposes (COCT 2013). The second biggest

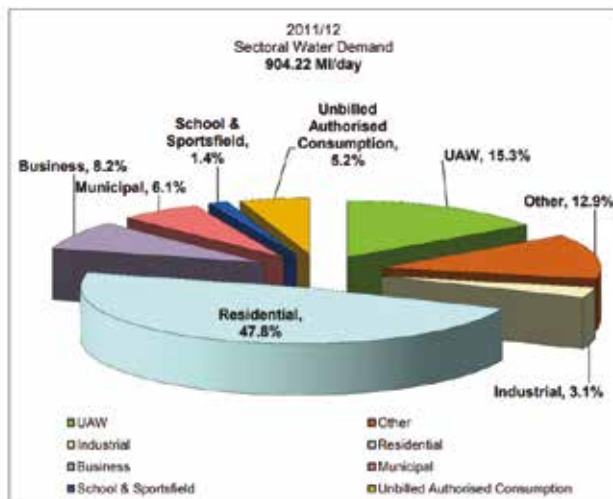


Figure 1: Sectoral Water Usage 2011/12 (Source: City of Cape Town 2013)

sectoral consumer at 15.3% is Unaccounted for Water (UAW) which includes reticulation losses through leaks and apparent losses (inaccurate meters) as well water theft, followed by Other at 12.9%, Business at 8.2%, Municipal at 6.1%, and Industrial at 3.1% (COCT 2013).

Of particular interest to this study is the water demand chart of the city (Figure 2): while the report notes that the WCWDM has been effective in terms of reducing demand, the system yield is shown flat under a normal climate scenario and negative under a climate change scenario (COCT 2013).

Of particular concern is the growing demand on the city's flat water yield: the city is adding approximately 2.5 million square metres of new building each year, with over 27 million square metres of new building added over the period 2006-2016 (see Table 2).

The graph indicates that the system yield reaches a tipping point at 2023 under the climate change scenario, and 2025 under a no climate change scenario with a 100% implementation success rate. These dates shift

to 2021 and 2022 respectively under a 50% implementation success rate (COCT 2013).

The importance of the role of municipalities in water conservation is evident in Table 1: municipalities are the second largest consumers of water in South Africa after irrigation (FOA 2016). In addition, municipalities are also a major producer of non-conventional sources of water, namely municipal wastewater (FOA 2016). This non-conventional source of water is almost equal to the municipal water withdrawal.

The total produced municipal wastewater volume amounts to 3 542 million m<sup>3</sup> in 2009 (Table 1), of which 54 percent is treated. However, half of the treatment plants, especially the smaller ones, do not meet the effluent standards, resulting in the quality of surface water being particularly poor in urban areas (OECD 2013).

### Renewable Water

Given the scarcity of water in South Africa, and climate change projections indicating a

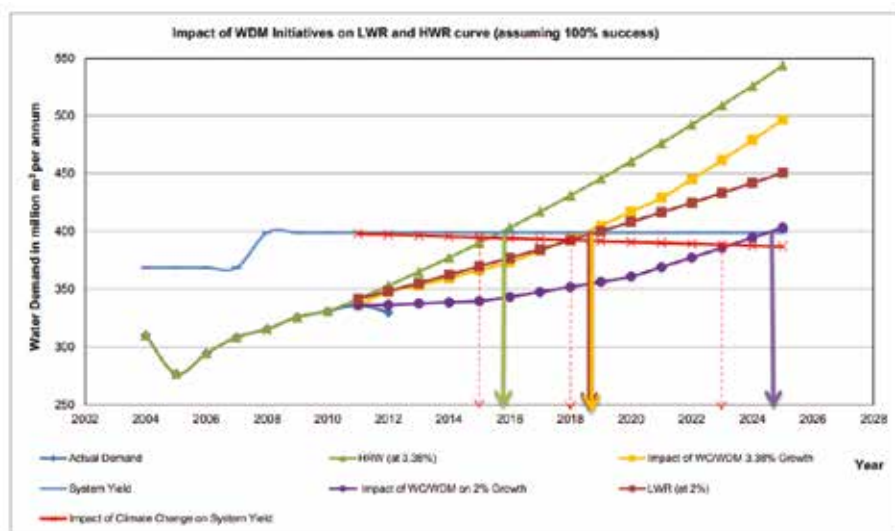


Figure 2: Impact of WCWDM on LWR and HWR curve including impacts of climate change on system yield (100% success)



generally hotter and drier future, focus has to shift to developing new water conservation and water efficiency measures.

Renewable water resources are resources that have an average annual inflow of water from surface water and groundwater (FOA 2017). Non-renewable water resources are deep aquifers that have a negligible rate of recharge on the human time-scale (FOA 2017). Not all natural freshwater, surface water or groundwater is accessible for use. Some water resources are too expensive to exploit, some resources are unfit for human consumption, while minimum levels need to be maintained in other water resources for aquatic health. Internal renewable water resources (IRWR) are that part of the water resources (surface and groundwater) generated from endogenous precipitation (FOA 2017). Surface water is the water in rivers and lakes while groundwater is the water captured in underground reservoirs.

Given the pressures on freshwater, other non-conventional sources of water are growing in importance. These non-conventional sources of water represent complementary supply sources that may be substantial in regions affected by extreme scarcity of renewable water

resources. Non-conventional resources include the production of freshwater by desalination of brackish or saltwater, and the reuse of waste water (with or without treatment), which increases the overall efficiency of use of water.

There are a number of water resources that can be harvested for recycling and reuse including rainwater, stormwater, greywater, groundwater and condensate.

**Rainwater harvesting** is the harvesting of precipitation from rooftops and collected in rainwater tanks either at ground level or below ground in cisterns. Rainwater has the advantage of being relatively free of contaminants compared to other sources of harvested water listed below, and therefore requires less treatment than those sources.

**Stormwater harvesting** is the collection of precipitation collected off outdoor ground level surfaces. In urban areas this water may be contaminated by oils and fluids, unknown chemical spills, animal faeces and urine, and nitrates and pesticides from landscaping. Because of this groundwater requires additional filtration and cleaning before it can be put to use. Typically stormwater is collected off road surfaces and discharged through an

Water withdrawal			
Total water withdrawal	2013	15 500	Million m <sup>3</sup> /year
Irrigation	2013	9 300	Million m <sup>3</sup> /year
Livestock	2013	<b>390</b>	Million m <sup>3</sup> /year
Municipalities	2013	4 185	Million m <sup>3</sup> /year
Industry	2013	1 625	Million m <sup>3</sup> /year
Per inhabitant	2013	294	m <sup>3</sup> /year
Non-conventional sources of water			
Produced municipal wastewater	2009	3 542	Million m <sup>3</sup> /year
Treated municipal wastewater	2009	1 919	Million m <sup>3</sup> /year
Direct use of treated municipal wastewater	2009	1 610	Million m <sup>3</sup> /year

Table 1: Water Use South Africa (Source: FOA 2016)

underground pipe system to a river or the sea. Storm water can be used for irrigation, to flush toilets, make-up water in evaporative cooling towers and more. Harvesting storm water reduces the burden on the municipal treatment system and saves the energy needed to transport and purify that water at the remote water treatment plant. It also reduces the inflow of pollutants from storm water into rivers, lakes and the sea. Storm water harvesting can also reduce the impact of flash floods. Storm water harvesting requires that the water entering the cistern is properly pre-treated. This entails, inter alia, a filtration process to remove hydrocarbons, debris, sediment and pollutants before the water enters the tank. Storm water harvested off non-parking pavements may require no more than being passed through a screen or vortex filter. Contaminants from parking surfaces require additional treatment to remove any additional contaminants. Typically storm water harvesting tanks consist of a screening system to capture and store debris in a dry state which minimizes nutrient leaching, bacteria growth, bad odours and allows for easier removal. Organics are captured in the filtration screen as sediments settle to the bottom chambers. Tanks are constructed in precast concrete units and are available in a range of sizes. Depending on the intended use of the harvested storm water the water can be treated with an ultra violet light and/or chlorination using calcium hypochlorite briquettes to produce highly concentrated chlorine liquid.

*Greywater harvesting* involves the harvesting of water from baths, showers and hand basins, and could include ponds, pool backwash or process rinse water. Toilet water and kitchen sink water is generally referred to as black water and is excluded from greywater. Greywater is generally reused to flush toilets, but can be recycled for other purposes if cleaned. The advantage of harvesting greywater is that there is an almost constant supply of water. The current Level 4b maximum water consumption per person per day in Cape Town is 87l, most

of which will end up as greywater. Greywater requires treatment as it contains biological and chemical contaminants that can turn the water to septic “black water” with concomitant health risks. Treating greywater to near-potable quality requires filtration, sanitation and monitoring steps.

*Black water harvesting* is the harvesting of water from toilets and kitchen sinks. There are systems certified by Agrément South Africa that treat black water, reusing the water while producing a sludge that has to be removed and disposed of periodically.

*Groundwater harvesting* is of water from below ground sources typically aquifers. Water is accessed through boreholes or wells. Groundwater tends to be the cleanest and best suited for recycling than other renewable sources, although in many parts of South Africa groundwater tends to be brackish (FOA 2017).

*Condensate harvesting* is the harvesting of condensate that comes from cooling coils of any air-conditioning system. It is an excellent source of clean water that can be either directed back into the cooling tower system or for other uses, such as topping up a rainwater and/or storm water harvesting system, with minimum treatment. Like greywater harvesting, condensate harvesting provides a steady supply source especially during the generally drier summer season.

## **The Application of Renewable Water Resources in Cape Town**

Generally rainwater harvesting in South Africa is insufficient to provide the required water supply throughout the year due to the relatively low annual rainfall. Groundwater is limited in South Africa due to the geology of the country and large porous aquifers occur only in a few areas (FOA 2016). Furthermore, because of the uneven temporal and spatial distribution of rainfall, 43 percent of the rain falls on only 13 percent of the land (FOA 2016). Therefore the goal for renewable water efficiency in South

African cities should be to collect every drop of precipitation, and to reuse every drop of precipitation harvested.

The harvesting and reuse/recycling of water will be most effective when multiple on-site sources are harvested, i.e., rainwater, storm water, greywater, black water, groundwater and condensate. As stated, both greywater and condensate have the advantage of providing a relatively constant supply throughout the year. Combined harvesting and treatment can provide a new standard of 'on-site treated non-potable' water similar to rainwater and storm water when treated. Clearly a single system is more complex than a system used solely for rainwater or storm water and will need to be designed for multiple applications.

## Limitations, Delimitations and Assumptions

### Limitations

Data is sourced from Statistics South Africa's Statistical Release P5041.3 *Selected building statistics of the private sector as reported by local government institutions*. As noted in the statistical release "data published in this statistical release are based on a monthly survey of metropolitan municipalities and large municipalities on building plans passed and buildings completed for the private sector, released monthly at national and provincial level as P5041.1." The annual release contains aggregated data for the twelve months of each year by province, municipality and type of buildings.

The following limitations apply:

The statistical data is for buildings completed by the private sector and thus this study excludes any buildings completed by the public sector.

The statistical data does not record the number of floors in any building completed, and thus an assumption has been made for each type of building (see assumptions).

The statistical data does not record the total square metres of internal alterations: it

does however record the value of internal alterations and thus an assumption is made of how many square metres that might represent (see assumptions).

Although the statistical data for the City of Cape Town is disaggregated into smaller councils, the geographical area of these councils do not correspond to available weather data and therefore annual rainfall data for the City of Cape Town as a whole is used. It is recognized that rainfall data for the city will differ across the peninsula.

### Delimitations

#### The following delimitations apply:

The study focuses on the City of Cape Town only. As such it excludes parts of the Cape Peninsula that would generally be considered as 'part' of Cape Town i.e., Drakenstein, Stellenbosch, and Swartland. A similar study would be required on each of the municipalities drawing water from the dams of the Western Cape to determine the overall impact of renewable water use on dam levels.

The study focuses on the use of rainwater only. The detailed use of stormwater, greywater, blackwater, groundwater and condensate are excluded.

The study uses data captured in the statistical release as 'buildings completed' and not 'building plans passed' as it may be that a building plan passed is not necessarily built immediately or at all.

### Assumptions

In the absence of more specific data with regard to the actual roof area of the building completed the study makes the following assumptions:

Based on the building description used by StatsSA a roof coverage factor is assumed to accommodate single storey (factor of 1), double storey (factor of 0.5) and multi-storey buildings not exceeding four storeys (factor of 0.25). Where a combination of single-and double-storey buildings is likely to occur in

equal measure, the two factors are averaged (factor of 0.75). This factor is applied to the total square meters of building completed to arrive at possible roof area.

StatsSA (2006) describes a dwelling house as a “free-standing, complete structure on a separate stand or a self-contained dwelling unit, granny flat, on the same premises as an existing residence”: given the inclusion of granny flats it can be assumed that dwelling houses include single-and double-storey buildings. The data does not indicate the number of floors in the completed building. For purposes of this study it is assumed that the ‘30 sq.m.’ and ‘80 sq.m.’ buildings are most likely single storey therefore a roof area factor of 1.0 is used; the ‘larger than 80 sq. m.’ most likely an equal combination of single and double storey therefore a roof factor of 0.75 is used (half being one storey and half being double storey); ‘flats’ most likely four storeys therefore a roof factor of 0.25 is used; ‘townhouses’ most likely to be an equal combination of single and double storey therefore a roof factor of 0.75 is used; and ‘other’ to be four storey therefore a roof factor of 0.25 is used.

Blocks of flats are described as “high-density housing consisting of a number of self-contained dwelling units”: given the notation as high-density it can be assumed that these buildings are multi-storey.

Other residential buildings include “homes for the disabled, boarding houses, hostels and tourism accommodation e.g. hotels, motels, guesthouses, holiday chalets, bed-and-breakfast accommodation and casinos”: given the inclusion of tourism accommodation, it can be assumed that the majority of these buildings will be double storey.

Non-residential building are dealt with similarly: it is assumed that ‘Office and banking space’ are multi-storey and a roof factor of 0.25 is used; it is assumed that ‘Shopping space’ is double storey and a roof factor of 0.5 is used; and it is assumed that ‘Industrial and warehouse’ is single storey and a roof factor of 1.0 is used.

Additions and alterations are dealt with similarly. It is assumed that additions and alterations to below 30 square metre dwellings is not significant and is therefore discounted from the calculations. The 30-80 and above 80 square metre dwelling houses are combined and averaged to provide a roof factor of 0.85. The statistical data does not indicate how many square metres of additions and alterations are internal but does provide a total value for internal alterations. This value is used as a percentage of the total value for additions and alterations for residential and non-residential buildings and then applied to the total square metres of additions and alterations for residential and non-residential building to calculate the net square metres of additions and alterations.

## Rainwater Harvesting

As noted above, rainwater harvesting is the collection and storage of rainwater from roof surfaces. Using the annual rainfall figures for Cape Town, and the area of buildings completed in the municipality, it is possible to calculate the volume of rainfall that could be harvested annually and could either be added to the system supply, or be deducted from the water demand.

## Rainwater Yield Calculation Methodology

For purposes of this study, data captured in Statistics South Africa’s (StatsSA) Statistical release P5041.3 which records annual selected building statistics of the private sector is used. StatsSA records the type, number, square metres and value of building plans passed and buildings completed.

Building data are recorded by type (residential, non-residential, and alterations and additions). In the case of residential buildings this is further disaggregated into dwelling houses, flats and townhouses, and other residential buildings and tourism accommodation. Dwelling houses are further

disaggregated into dwellings equal to or smaller than 30 square metres; larger than 30 square metres; and equal to or larger than 80 square metres. Non-residential buildings are disaggregated into office and banking space; shopping space; industrial and warehouse space; schools, nursery schools, crèches and hospitals; churches, sport and recreation clubs; and all other non-residential space.

Table 2 provides the number and total square metre of residential buildings, non-residential buildings and additions and alterations reported as completed in the City of Cape Town for the period under review, namely 2006 - 2016.

The data in Table 2 is further disaggregated in Table 3, Table 4 and Table 5 for residential, non-residential, and additions and alterations respectively.

Additions and alterations may not always add roof area to the building, i.e., additions and alterations may be internal. The statistical data does not indicate how many square metres are external or internal. However, statistical data does include the value of internal additions and alterations. Table 6 indicates the value of internal alterations as a percentage of total additions and alterations

value: this is used to discount the floor area of total additions and alterations.

Using the statistical data from the above tables the assumed roof areas can be calculated. The roof factor is applied to each building type per year.

**Table 7: Assumed roof areas: residential: City of Cape Town: 2006-2016**

The same methodology is used to calculate the roof area of non-residential buildings.

**Table 8: Assumed roof areas: non-residential: City of Cape Town: 2006-2016**

Rainwater Yield

Having calculated the total roof area for buildings completed, and using the rainfall for each year (TuTiempo 2017), the potential total volume and mega litres of water available from rainwater harvesting can be calculated.

**Table 9: Rainwater harvesting calculation**

The calculation indicates that 7 864 ML of water would have been added to the water yield if rainwater harvesting had been made compulsory for all new building work completed between 2006 and 2016.

Year	Residential	Non-residential	Additions and additions	Total
2006	1 561 899	426 030	845 533	2 833 462
2007	1 558 110	683 054	830 772	3 071 936
2008	1 411 462	759 628	1 100 439	3 271 529
2009	1 252 582	736 006	1 034 419	3 022 987
2010	898 515	382 923	756 667	2 038 105
2011	864 727	377 793	756 566	1 999 086
2012	915 066	473 554	633 809	2 022 429
2013	1 194 410	649 544	1 059 688	2 903 642
2014	750 780	383 492	439 994	1 574 266
2015	1 025 890	570 718	484 924	2 081 532
2016	1 075 153	549 318	582 420	2 206 891
<b>Total</b>	<b>12 508 594</b>	<b>5 992 060</b>	<b>7 679 799</b>	<b>27 075 865</b>

Table 2: Number and square metres of residential buildings, non-residential buildings and additions and alterations reported as completed: City of Cape Town: 2006-2016

Year	Dwelling houses Sq.m.	Factor *	Flats sq.m.	Factor	T'houses Sq.m.	Factor	Other Sq.m.	Factor	
2006	<30	39 493	1.0	367 245	0.25	221 103	0.75	17 791	0.25
	30-80	132 904	1.0						
	>80	783 363	0.75						
2007	<30	48 702	1.0	395 214	0.25	178 413	0.75	48 376	0.25
	30-80	174 897	1.0						
	>80	712 508	0.75						
2008	<30	4 023	1.0	281 428	0.25	161 487	0.75	13 866	0.25
	30-80	162 644	1.0						
	>80	766 883	0.75						
2009	<30	4 394	1.0	282 073	0.25	77 640	0.75	13 753	0.25
	30-80	230 066	1.0						
	>80	569 460	0.75						
2010	<30	1 835	1.0	191 219	0.25	47 577	0.75	48 300	0.25
	30-80	224 754	1.0						
	>80	384 830	0.75						
2011	<30	631	1.0	141 925	0.25	62 164	0.75	36 049	0.25
	30-80	152 161	1.0						
	>80	471 797	0.75						
2012	<30	1 720	1.0	179 828	0.25	66 570	0.75	1 549	0.25
	30-80	216 423	1.0						
	>80	448 976	0.75						
2013	<30	2 357	1.0	240 072	0.25	102 284	0.75	30 203	0.25
	30-80	276 034	1.0						
	>80	543 460	0.75						
2014	<30	29	1.0	141 730	0.25	30 925	0.75	26 727	0.25
	30-80	199 070	1.0						
	>80	352 300	0.75						
2015	<30	60	1.0	202 213	0.25	58 179	0.75	9 610	0.25
	30-80	229 587	1.0						
	>80	526 241	0.75						
2016	<30	217	1.0	281 185	0.25	76 898	0.75	9 181	0.25
	30-80	185 895	1.0						
	>80	521 777	0.75						

Table 3: Square metres of residential buildings reported as completed: City of Cape Town: 2006-2016

Year	Office and banking space	Factor	Shopping space	Factor	Industrial and warehouse	Factor	Other	Factor
2006	50 292	0.25	71 190	0.5	259 537	1.0	28 499	0.25
2007	212 874	0.25	68 351	0.5	344 670	1.0	27 876	0.25
2008	230 509	0.25	152 807	0.5	346 816	1.0	3 527	0.25
2009	217 839	0.25	152 439	0.5	319 220	1.0	1 740	0.25
2010	49 645	0.25	113 390	0.5	151 647	1.0	25 595	0.25
2011	69 342	0.25	104 146	0.5	131 181	1.0	45 278	0.25
2012	56 662	0.25	124 813	0.5	262 232	1.0	2 162	0.25
2013	167 193	0.25	169 383	0.5	244 808	1.0	18 872	0.25
2014	127 656	0.25	20 994	0.5	193 190	1.0	12 563	0.25
2015	202 595	0.25	99 686	0.5	206 942	1.0	18 959	0.25
2016	134 716	0.25	71 837	0.5	243 218	1.0	12 686	0.25

Table 4: Square metres of non-residential buildings reported as completed: City of Cape Town: 2006-2016

Year	Dwelling houses	Factor	Other residential	Factor	Non-residential	Factor
2006	607 850	0.875	28 415	0.5	209 268	0.5
2007	603 208	0.875	24 555	0.5	203 009	0.5
2008	798 234	0.875	25 355	0.5	276 850	0.5
2009	790 469	0.875	15 957	0.5	227 993	0.5
2010	529 725	0.875	18 727	0.5	208 215	0.5
2011	539 235	0.875	14 519	0.5	202 812	0.5
2012	477 123	0.875	15 479	0.5	141 207	0.5
2013	721 546	0.875	44 473	0.5	293 669	0.5
2014	294 310	0.875	11 309	0.5	134 375	0.5
2015	384 268	0.875	4 777	0.5	95 879	0.5
2016	416 509	0.875	15 100	0.5	105 811	0.5

Table 5: Square metres of recorded buildings recorded as completed for additions and alterations: City of Cape Town: 2006-2016

Year	Internal alterations: total value R'000	Total value additions and alterations R'000	Internal alterations as a % of total additions and alterations
2006	99 526	2 181 291	4,56
2007	147 771	2 357 770	6,26
2008	339 662	3 365 858	10,09
2009	227 684	3 310 440	6,87
2010	192 768	2 680 343	7,19
2011	199 769	2 850 502	7,00
2012	394 986	2 820 034	14,00
2013	481 411	4 644 223	10,36
2014	219 641	2 292 790	9,57
2015	356 362	2 849 721	12,50
2016	430 369	3 577 695	12,02

Table 6: Value of internal alterations as a percentage of total additions and alterations value: City of Cape Town: 2006-2016

Table 7: Assumed roof areas: residential: City of Cape Town: 2006-2016

Year	<30	30-80	>80	Flats	T'houses	Other	Alt	Total
2006	39 493	132 904	587 522	91 811	165 827	4 447	507850	1 529 856
2007	48 702	174 897	534 381	98 803	133 809	12 094	502278	1 504 966
2008	4 023	162 655	575 162	70 357	121 115	3 466	640 019	1 576 798
2009	4 394	230 066	427095	70 518	58 230	3 438	650 664	1 444 406
2010	1 835	224 754	288 622	47 804	35 682	12 075	439 771	1 050 546
2011	631	152 161	353 847	35 481	46 623	9 012	445 553	1 043 310
2012	1 720	216 423	336 732	44 957	49 927	387	365 691	1 015 838
2013	2 357	276 034	407 595	60 018	76 713	7 550	588 230	1 418 498
2014	29	199 070	264 225	35 432	23 193	6 681	236 858	765 490
2015	60	229 587	394 680	50 553	43 634	2 402	297 988	1 018 906
2016	217	185 895	391 332	70 296	57 673	2 295	327 355	1 035 066
<b>Total</b>	<b>103 461</b>	<b>2 184 446</b>	<b>4 561 196</b>	<b>676 033</b>	<b>812 430</b>	<b>63 851</b>	<b>5 002 262</b>	<b>13 403 679</b>

Table 7: Assumed roof areas: residential: City of Cape Town: 2006-2016

Year	Office and banking	Shopping	Industrial and warehouse	Other	Additions and alterations	Total
2006	12 573	35 595	259 537	7 124	99 402	414 232
2007	53 218	34 175	344 670	6 969	95 414	534 447
2008	57 627	76 403	346 816	881	124 582	606 311
2009	54 459	76 219	319 220	435	107 156	557 490
2010	12 411	56 695	151 647	6 398	96 819	323 972
2011	17 335	52 073	131 181	11 319	94 307	306 216
2012	14 165	62 406	262 232	540	60 719	400 063
2013	41 798	84 691	244 808	4 718	131 151	508 166
2014	31 914	10 497	193 190	3 140	60 468	299 210
2015	50 648	49 843	206 942	4 739	42 186	354 360
2016	33 679	35 918	243 218	3 171	46 556	362543
<b>Total</b>	<b>379 830</b>	<b>574 518</b>	<b>2 703 461</b>	<b>49 439</b>	<b>959 765</b>	<b>4 667 014</b>

Table 8: Assumed roof areas: non-residential: City of Cape Town: 2006-2016

Year	Total roof area: residential	Total roof area: non residential	Total roof area: all buildings	Rainfall annual (mm)	Rainwater harvesting factor	Volume of water m3	Ml water annum
2006	1 529 856	414 232	1 944 088	500	0.85	826 237	826.23
2007	1 504 966	534 447	2 039 413	500	0.85	866 750	866.75
2008	1 576 798	606 311	2 183 109	542.10	0.85	1 005 758	1 005.75
2009	1 444 406	557 490	2 001 896	575.07	0.85	978 426	978.42
2010	1 050 546	323 972	1 374 518	500	0.85	584 170	584.17
2011	1 043 310	306 216	1 349 526	373.36	0.85	427 867	427.86
2012	1 015 838	400 063	1 415 901	500	0.85	601 757	601.75
2013	1 418 498	508 166	1 926 664	576.02	0.85	943 294	943.29
2014	765 490	299 210	1 064 700	500	0.85	452 497	452.49
2015	1 018 906	354 360	1 373 266	500	0.85	583 633	686.63
2016	1 035 066	362 543	1 397 609	500	0.85	698 638	583.63
<b>Total</b>	<b>13 403 679</b>	<b>4 667 010</b>	<b>18 070 690</b>	<b>500</b>	<b>0.85</b>	<b>7 864 382</b>	<b>7 864.39</b>

Table 9: Rainwater harvesting calculation

## Conclusion

All climate change models suggest that a major impact of climate change will be a hotter and drier South Africa. Both impacts pose significant risks to water security: higher temperatures mean higher rates of evaporation, while drier spells mean lower rates of precipitation. The combination will significantly increase water stress and reduce water security. Under this scenario every drop of precipitation needs to be conserved.

Given the pressures on freshwater, other non-conventional sources of water are growing in importance. These non-conventional sources

of water represent complementary supply sources that may be substantial in regions affected by extreme scarcity of renewable water resources.

This study finds that enforcing rainwater harvesting and storage for all new buildings can generate significant additional water storage capacity in the city.

Rainwater and stormwater harvesting therefore appears to be feasible in Cape Town but it will depend on whether all sectors of society would be willing to use harvested rainwater and stormwater, and whether the required municipal policy and regulatory



## Discussion

Water resources management (WRM) involves, inter alia, developing infrastructure to store and transport water to users; allocating the resource to different users; implementing incentives for its efficient use; and protecting it. It also involves the financing and ongoing operational management of all these activities. Muller et al. (2009) describes a logical sequence to these activities:

Initially, the focus of individual users is on the physical infrastructure required to take the water from the source and transport it to where it is needed.

As the quantity used increases, the focus shifts to providing water security, by storing enough water to sustain supply during dry periods.

As the number of users in an area grows, the need to develop at least part of this capacity as a collective or public infrastructure increases.

As the intensity of water use grows, it becomes more important to have a formal system for allocating available water to individual users. Thus, when demand grows to exceed supply, there will be a clear mechanism for managing competition among users.

As increased water use is often associated with increased generation of wastewater, the protection of the resource from uncontrolled

pollution requires greater attention. (Muller et al., 2009).

The same holds for the harvesting and use of rainwater and stormwater. The long-term sustainability of rainwater and stormwater harvesting initiatives is dependent on promoting the active participation of residents and consumers. Experiences in many countries show that where community participation and ownership are fostered, more will be accomplished at lower costs, people are freed from dependence on others' skills, indispensable indigenous knowledge is used, health benefits are maximised, individual projects are more likely to be self-sustaining, and further responsible development takes place by the community (SOPAC, 2004).

Further research

In the absence of more detailed data this study relies on certain assumption, especially with regard to the determination of roof area. More detailed data is necessary to accurately calculate the total roof area added each year. This will also have to include data from other municipalities that rely on existing water storage in the greater Cape Town area.

The safe storage and treatment of rainwater will be critical to its success: further research is required to determine what these options may include.

## References

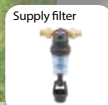
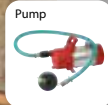
- COCT 2013. Update and additions to existing long-term water conservation and water demand management strategy: water and sanitation. Cape Town: City of Cape Town.
- Dillon, P., Page, D., Lim, M.H., Lee, E., Lim, P.Y., Devitt, C., Vanderzalm, J., Toze, S. and Hyde, K. (2011). Health risk assessment for use of urban stormwater as a drinking water supply. Proc. Singapore Intl. Water Week Symp. 4-8 July 2011.
- FOA 2017. Review of world water resources by country. New York: Food and Agriculture Organization of the United Nations.
- FOA 2016. South Africa. [Online] Available from: [http://www.fao.org/nr/water/aquastat/countries\\_regions/ZAF/](http://www.fao.org/nr/water/aquastat/countries_regions/ZAF/) [Accessed: Monday, 24 July 2017].
- Muller, M., Schreiner, B., Smith, L., Van Koppen, B., Sally, H., Aliber, M., Cousins, B., Tapela, B., Van der Merwe-Botha, M., Karar, E. and Pietersen, K. 2009. Water security in South Africa. Develop-

ment Planning Division, Working Paper Series No.12. DBSA, Midrand.

- StatsSA 2006. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2007. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2008. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2009. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2010. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2011. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2012. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2013. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2014. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2015. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- StatsSA 2016. Selected building statistics of the private sector as reported by local government institutions. Statistical release P5041.3. Pretoria: Statistics South Africa.
- SOPAC. 2004. Harvesting the Heavens: Guidelines for Rainwater Harvesting in Pacific Island Countries. Compiled by the South Pacific Applied Geoscience Commission (SOPAC) for the United Nations Environment Programme (UNEP) in conjunction with the Tonga Community Development Trust (TCDT) and funded by The Swedish International Development Agency (SIDA). Suva, Fiji Islands.
- TuTiempo 2017. [Online] <https://en.tutiempo.net/climate/ws-688160.html> [Accessed: Thursday, 31 August 2017].

# Rainwater & Stormwater Solutions

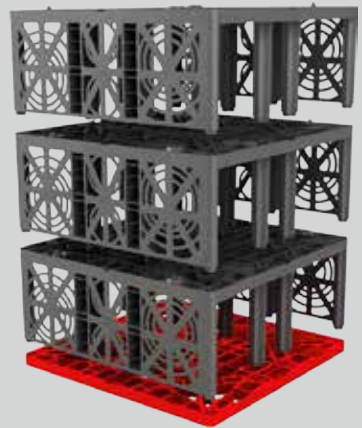
## Rainwater Harvesting



- Professional rainwater harvesting systems for domestic and commercial applications
- Complete package solutions with single tank capacities of 4,800 L and 6,500 L
- Multiple tanks connected for larger systems
- Suitable for drive way installations
- Automatic switch-over between tank and municipal supply

## Stormwater Infiltration & Harvesting - Industrial

- Universal use: For rainwater infiltration, retention or rainwater harvesting (50,000 L and above)
- Modular system structure with 205 L per element
- Heavy-duty lorry-bearing capacity of 60 tons
- Installation depth of up to 5 meters
- Designed for a long service life



## Water Infiltration Tunnels - Residential

- 300 L capacity per element
- Multiple elements for larger volumes
- Vehicle loading up to 3.5 t/m<sup>2</sup>
- Suitable as a french drain for septic tanks



# Chapter 3

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## Harvesting Renewable Water: Part 2: Stormwater

— Llewellyn van Wyk, Pierre du Plessis

## Introduction

As noted elsewhere in this publication (Harvesting renewable water: Part 1: Rainwater) South Africa is a water scarce country. This status is likely to be aggravated by projected climate change impacts, which forecasts a hotter and drier future for the country (Engelbrecht, Adegoke, Bopape, Naidoo, Garland, Thatcher, McGregor, Katzfey, Werner, Ichoku and Gatebe 2015). Cape Town is in the throes of an extended drought, with dam levels at 34.2 percent (City of Cape Town 2017).

This scenario is not unique to the city, or to the country. The rainfall climate of South Africa is one of great variability with wide fluctuations about the long-term average. As published by the South African Weather Service, "between July of 1960 and June of 2004, there have been 8 summer-rainfall seasons where rainfall for the entire summer-rainfall area has been less than 80% of normal" (SAWS 2017). A deficit of 25% is normally regarded as a severe meteorological drought but it can be safely assumed that a shortfall of 20% from normal rainfall will cause crop and water shortfalls in many regions accompanied by social and economic hardship.

Under a low and fluctuating precipitation scenario, every opportunity to harvest and store rainfall is therefore critical. This chapter argues that the harvesting of stormwater can make a significant contribution to water security. This approach has been adopted in other cities internationally, and most notably in China under the Sponge City (SPC) Programme. This programme is a direct response to manage both urban flooding and water conservation: the goal is that by 2020 80% of urban areas should absorb and re-use at least 70% of rainwater (Biswas and Hartley 2017).

The chapter calculates the volume of renewable stormwater harvesting possible for the urban area of Cape Town for 2013. The year 2013 is used because it is the most recent year where accurate annual rainfall is readily available.

## Methodology

- The method used to determine the water volume is as follows:
- Calculate net urban area to exclude nature reserves and farmland
- Classify sub-classes within the urban area
- Use the rainfall runoff factor applicable to each sub-class to allow for different surface types
- Calculate volume for the period using annual rainfall figures

### Calculate the net urban area

The City of Cape Town covers a total area of 2 447km<sup>2</sup> of which 53.8% (1 316km<sup>2</sup>) consists of built up areas classified as "Urban".

In order to calculate the total area covered by the urban class the 2013-14 GTI SA National Land-Cover (NLC) dataset was used. The NLC dataset has been created by GEOTERRAIMAGE (GTI) and was derived from multi-seasonal Landsat 8 imagery, using operationally proven, semi-automated modelling procedures developed specifically for the generation of this dataset and is based on repeatable and standardised modelling routines. The dataset is based on 30x30m (900m<sup>2</sup>) raster cells (grid) and is ideally suited for landscape planning, inventory and management activities, ranging from environmental resource management to telecommunication planning.

The NLC dataset consists of 72 land-cover/ use classes, covering a wide range of natural and man-made landscape characteristics and each 30x30m raster cell contains a single code representing the dominant land-cover class (by area). Table 1 describes the built-up class and the various sub-classes constituting urban.

\* Note: All Built-Up classes except "Commercial", "Industrial" and "School and Sports Grounds" are sub-divided according to whether the surface area is dominated by tree, bush, grass or bare surface

characteristics. This allows for re-construction of a "pure" land-cover surface if required. For example

Sub-classes with urban class	Description
42 Commercial	Areas containing high density buildings and other built-up structures associated with mainly non-residential, commercial, administrative, health, religious or transport (i.e. train station) activities. Note that in some areas his class may include tall, multi-storey residential flat units.
43 Industrial	Areas containing buildings and other built-up structures associated with mainly non-residential, industrial and manufacturing activities, including power stations.
44,45,46,47 Informal	Areas containing high density buildings and other built-up structures typically associated with informal, often non-regulated, residential housing. Note that in some areas this class may include new formal developments within township areas that appear on Landsat imagery as primarily non-vegetated areas with limited infrastructure development.
48,49, 50,51 Residential	Areas containing variable density buildings and other built-up structures typically associated with formal, regulated, residential housing. Includes well established suburbs, townhouses, hostel complexes, flats etc.
52 Schools & Sports	Areas containing buildings, other built-up structures and open sports areas typically associated with schools and school sports grounds. Image identification of such features is based on the local spatial relationship between the buildings and open area, thus small urban schools without adjacent open areas may have been missed.
53,54,55,56 Smallholding	Areas containing a low density mix of buildings, other built-up structures within open areas, which may or may not be cultivated, that are representative of formally declared agricultural holdings, and similar small holdings / small farms, typically located on the periphery of urban areas.
57,58,59, 60 Sports & Golf	Areas containing a low density mix of buildings, other built-up structures associated with golf courses. The class includes both residential golf estates and non-residential golf courses, and typically represents the border extent of the entire estate or course.
61,62,63,64 Township	Areas containing high density buildings and other built-up structures typically associated with formal, regulated, residential housing associated with townships and "RDP" type housing developments.
65,66,67,68 Village	Areas containing variable density structures typically associated with rural villages, including both traditional and modern building formats.
69, 70,71,72 Built-up	Areas containing variable densities of buildings other built-up structures, or no structures at all, that are not clearly identifiable as one of the other Built-Up classes. May include runways, major infrastructure development sites, holiday chalets, roads, car parks, cemeteries etc.

Table 1: Urban Land-cover classes (source 2013-14 SA NLIC dataset User and Metadata report)

Table 2: Classification, area and percentage of sub-classes

Count	Class Name	Area (sq.m.)	Percentage
13	Urban informal (open trees/bush)	11 700	0.0009
1 279	Urban informal (dense trees/bush)	1 151 100	0.0970
10 367	Urban informal (low veg/grass)	9 330 300	0.7864
11 200	Urban informal (bare)	10 080 000	0.8496
23	Urban built-up (open trees/bush)	20 700	0.0017
509	Urban built-up (dense trees/bush)	458 100	0.0386
1 782	Urban built-up (low veg/grass)	1 603 800	0.1351
22 743	Urban built-up (bare)	20 468 700	1.7252
216	Urban township (open trees/bush)	194 400	0.02
4 023	Urban township (dense trees/bush)	3 620 700	0.31
42 987	Urban township (bare)	38 688 300	3.26
62 288	Urban township (low veg/grass)	56 059 200	4.73
291	Urban sports and golf (open tree/bush)	261 900	0.02
648	Urban sports and golf (bare)	583 200	0.05
17 700	Urban sports and golf (low veg/grass)	15 930 000	1.34
18 663	Urban sports and golf (dense tree/bush)	16 796 700	1.42
370	Urban smallholding (open trees/bush)	333 000	0.03
14 174	Urban smallholding (dense trees/bush)	12 756 600	1.08
42 776	Urban smallholding (low veg/grass)	38 498 400	3.24
564	Urban smallholding (bare)	507 600	0.04
1 612	Urban residential (open trees/bush)	1 450 800	0.12
146 973	Urban residential (dense trees/bush)	132 275 700	11.15
145 288	Urban residential (low veg/grass)	130 759 200	11.02
8 565	Urban residential (bare)	7 709 400	0.65
28 023	Urban school and sports ground	25 220 700	2.13
54 028	Urban industrial	48 625 200	4.10
72 404	Urban commercial	65 163 600	5.49

- 48 Residential (tree dominated)
- 49 Residential (bush dominated)
- 50 Residential (grass dominated)
- 51 Residential (bare dominated).

The methodology used for calculating the total areas covered by the urban class was to discard

all non-urban classes from the dataset; this was done using Geographic Information System (GIS) software. A total of 30 distinct urban classes remained and the total area covered by each class was calculated using the following formula:

Table 3: Typical runoff coefficients

Surface	Coefficient
Lawns	0.35
Forest	0.25
Well established townships/suburbs	0.6
Newly established townships/suburbs with little vegetation	0.65
Business areas	0.95
Industrial areas	0.9
Cultivated land	0.41
Sandy soils covered by perennial grasses	0.25
Clayey soils covered by perennial grasses	0.3
Parks	0.25
Graded or No Plant Cover	0.35
Playgrounds	0.35

Total number of cells per class x 900

$A$  = area contributing to the runoff measured at a given point, m)

### Classification of sub-classes

The classification of sub-classes resulted in a table (Table 2) containing the total square meters of each class. For the purpose of calculating the total water harvesting potential of the built up area the sub-classes in each class was grouped together to produce a combined area per sub-class.

Opacity is '1' and Urban is '1' in each case.  
Stormwater runoff factor

The runoff rate for stormwater will vary depending on the runoff surface. Thus, more stormwater will runoff a hard surface than a permeable surface. The peak runoff from a rain event is determined by the following simplified formula:

$$Q = CIA$$

Where

$Q$  = peak runoff in  $m^3/s$

$C$  = Runoff coefficient (expressed as a decimal fraction of 1)

$I$  = rainfall intensity (depth of rainfall over time taken = m/s)

Runoff is also determined by the following factors:

- Slope of the land
- Coverage of the land (e.g. vegetated, roofs, little absorbing surfaces)
- Soil type (sandy/loam/clay)

Table 3 shows typical runoff coefficients (LMNO Engineering, 2017; Gwinnett County, 2017).

### Calculate volume of stormwater

Having determined the sub-classes, the area, and the rainfall intensity, it is possible to calculate the volume of stormwater that could potentially be harvested.

Based on the assumptions made for the study, the volume of stormwater for the Cape Town urban area in 2013 was 213 859.18 ML. This equates to 23.69% of the total dam storage capacity of the Western Cape of 902 598 ML, (City of Cape Town 2017b). This rainwater is being discharged to the sea where the future



Table 4: Potential volume of stormwater

Sub-class	Area (sq.m.)	Rainfall intensity (mm/annum)	Runoff coefficient	Volume (Q) Ml
Urban informal (Bare)	1 008 000	576.02	0.41	2 380.57
Urban informal (Low veg/grass)	9 330 300	576.02	0.35	1 881.05
Urban informal (Open trees/bush)	11 700	576.02	0.3	2.02
Urban informal (Dense trees/bush)	1 151 100	576.02	0.6	397.83
Urban built-up (Bare)	20 468 700	576.02	0.41	4 834.05
Urban built-up (Low veg/grass)	1 603 800	576.02	0.35	323.33
Urban built-up (Open trees/bush)	20 700	576.02	0.3	3.57
Urban built-up (Dense trees/bush)	458 100	576.02	0.6	158.32
Urban township (Bare)	38 688 300	576.02	0.41	9 136.94
Urban township (Low veg/grass)	56 050 200	576.02	0.35	11 301.92
Urban township (Open trees/bush)	194 400	576.02	0.3	33.59
Urban township (Dense trees/bush)	3 620 700	576.02	0.6	1 251.35
Urban sports (Bare)	583 200	576.02	0.35	117.57
Urban sports (Low veg/grass)	1 593 000	576.02	0.35	3 121.59
Urban sports (Open trees/bush)	261 900	576.02	0.35	45.25
Urban sports (Dense trees/bush)	16 796 700	576.02	0.25	2 418.80
Urban smallholding (Bare)	507 600	576.02	0.41	119.87
Urban smallholding (Low veg/grass)	38 498 400	576.02	0.35	7 761.54
Urban smallholding (Open trees/bush)	333 000	576.02	0.3	57.54
Urban smallholding (Dense trees/bush)	12 756 600	576.02	0.6	4 408.83
Urban residential (Bare)	7 709 400	576.02	0.65	2 886.49
Urban residential (Low veg/grass)	130 759 200	576.02	0.65	48 957.94
Urban residential (Open trees/bush)	1 450 800	576.02	0.6	501.41
Urban residential (Dense trees/bush)	132 275 700	576.02	0.6	45 716.06
Urban school and sportsground	25 220 700	576.02	0.35	5 084.66
Urban industrial	48 625 200	576.02	0.9	25 208.17
Urban commercial	65 163 600	576.02	0.95	35 658.76
TOTAL				213 859.18

intention is to desalinate it before being put back into the water reticulation system.

## **Sustainable Urban Drainage Systems (SuDS)**

Sustainable Urban Drainage Systems (SuDS) are systems which aim to manage surface water runoff for maximum benefit (CIRIA 2015). These benefits typically include four categories namely, water quantity, water quality, amenity, and biodiversity. The purpose of this chapter is not to provide a detailed report on SuDS, but to indicate that there are alternative solutions available to manage scarce water resources. Typical components of SuDS include:

- Rainwater harvesting
- Green roofs
- Infiltration systems
- Propriety systems
- Filter strips
- Filter drains
- Swales
- Bioretention systems
- Trees
- Pervious pavements
- Attenuation storage tanks
- Detention basins
- Ponds and wetland

As can be seen, the strategic utilisation of stormwater through SuDS provides numerous benefits over and above the utilization of the

resource. Given the existence of wetlands and aquifers in the Cape Town area, a potential SuDS design would be aimed at the replenishment of those components during the winter months, for withdrawal in the summer months.

## **Conclusion**

Cape Town, like other cities in South Africa, faces an uncertain water future: this requires that every effort is explored to utilize South Africa's water resources in the most conservative and efficient manner. Renewable water offers significant potential in this regard.

Utilizing the full range of SuDS components (many of which are already in place in Cape Town) offers significant benefits over and above its quantitative reuse of stormwater.

## **Further research**

This study has made a number of assumptions which require further research particularly with regard to runoff factors. Runoff factors are normally provided in a range for different conditions and further research will be required to determine the applicable factor in each instance. In addition, further mapping is required to overlay existing SuDS components, especially wetlands and aquifers, over the urban map to identify opportunities for aquifer replenishment.

## References

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- Biswas, A., and Hartley, K. 2017. Chian's 'sponge cities' aim to reuse 70% of rainwater. [Online] Available from: <http://edition.cnn.com/2017/09/17/asia/china-sponge-cities/index.html> [Downloaded: September 19, 2017].
- CIRIA 2015. CIRIA SUDS Manual. CIRIA C753. London: CIRIA.
- City of Cape Town 2017a. This week's dam levels. [Online] Available from: <http://www.cape-town.gov.za/Family%20and%20home/residential-utility-services/residential-water-and-sanitation-services/this-weeks-dam-levels> [Accessed: Friday, 08 September 2017].
- City of Cape Town 2017b. City of Cape Town water dashboard. [Online] Available from: <http://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/damlevels.pdf> [Downloaded: Wednesday, 13 September 2017].
- Engelbrecht, F., Adegoke, J., Bopape, MM., Naidoo, M., Garland, R., Thatcher, M., McGregor, J., Katzfey, J., Werner, M., Ichoku, C., and Gatebe, C. 2015. "Projections of rapidly rising surface temperatures over Africa under low mitigation." *Environmental Research Letters*.
- SAWS 2017. What kind of droughts does South Africa experience? [Online] Available from: <http://www.weathersa.co.za/learning/climate-questions/36-what-kind-of-droughts-does-south-africa-experience> [Accessed: Friday, 08 September 2017].

# Chapter 4

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## Sun and shade

— Dr Dirk Conradie, Senior researcher, CSIR Built Environment



## Introduction

South Africa is blessed with some of the best quality sunshine in the world but at the same time has some of the most intense solar radiation. There are therefore many exciting opportunities to utilize the sun to its full potential in the design of energy efficient and comfortable buildings. Previous chapters discussed various sun related aspects such as possible corrective actions in a very hot naturally ventilated office during the hottest summer in Pretoria (Conradie, 2016b), the optimisation of daylight in South Africa, the general weak thermal performance of fenestration (Conradie et al., 2015a), the use of glass in buildings (Conradie et al., 2015a), maximising use of the sun (Conradie, 2011) and passive design strategies (Conradie, 2013). Some of the articles were qualitative and others quantitative. There is a general paucity of information with regards the amount of incident solar radiation on the various building surfaces in the different climatic regions, cities and latitudes in South Africa.

Bioclimatic and other analyses of the major cities indicated clearly that appropriate solar protection is the single most important measure in all climatic regions. Passive solar buildings aim to maintain interior thermal comfort throughout the sun's daily and annual cycles whilst reducing the requirement for active heating and cooling systems.

This chapter continues on the basis of previous research, mentioned above, to quantify the energy benefits when various solar protection measures are applied to the different (east, north, west and south) and roof in all the climatic regions of South Africa. At the moment it is rather difficult to obtain such quantified information. The article also investigates the changes in solar protection, such as overhang sizes that will be required with an A2 scenario (business as usual) of climate change. An A2 climate change scenario as described by the Intergovernmental Panel on Climate Change (IPCC, 2000) is where the Representative CO<sub>2</sub> Concentration Pathways (RCPs) are set to

increase to 950 ppm, from a current basis of 400 ppm, by the year 2100 and even higher to 1 200 ppm after the year 2100. This RCP8.5 scenario corresponds to an energy increase of +8.5 W/m<sup>2</sup> by 2100. Insights are also provided how the overheated period can be determined when facades and especially windows need to be shaded. The article also touches on different types of solar radiation such as diffuse and direct and different types of shade such as the umbra, penumbra and antumbra. It continues with a discussion how the overhang sizes could be calculated to provide shading at the correct time of day and year.

## Methodology

The purpose of this chapter is firstly to determine the direct solar radiation on the various surfaces (east, west, north, south and roof) of a building in a representative range of cities/ towns (13) in South Africa. As an additional alternative check a bioclimatic analysis is used to quantify the number of hours that sun shading of windows will be beneficial in the various locations. Solar protection measures such as overhangs and vertical fins are then applied to these surfaces to determine the potential benefit. Lastly, as a worked example, the critical solar angles were calculated to achieve better solar control for Pretoria, currently and with an A2 climate change. Urban heat islands (UHI), albedo and shade are also discussed as it is closely related.

To support the solar radiation, bioclimatic analysis and the recommended solar angle calculations detailed weather files were generated with the Meteororm software for 13 cities using typical meteorological years based on measured data. A second set of weather files were generated to quantify the effect of climate change up to the year 2100 using an A2 climate change scenario of the Special Report on Emission Scenarios (SRES) for the period 1961-2100 using the first set as a baseline. An A2 scenario can also be described as Business As Usual (BAU). Recent climatic research indicates that this is unfortunately the most likely scenario for South Africa. Using these weather

files a comprehensive bioclimatic analysis was run by means of Climate Consultant 6.0 and Ecotect v5.60 to determine the direct solar radiation and to quantify the potential savings that appropriate solar protection measures will realise. The results are presented in normalized tables to make application more universally applicable.

## Background

Cities contribute significantly to global greenhouse gas emissions and on the other hand are also adversely affected by the effects of climate change caused by these emissions such as the complex problem of UHI effect. At the moment about half of the world's population live in cities. That is likely to increase to 70% by 2050. Cities use as much as 80% of all energy production worldwide (The International Bank for Reconstruction and Development & World Bank, 2010: 15). To address this situation a range of carbon emission mitigation strategies have been developed including:

## Use of renewable energy

Commercial and residential energy efficiency

- Solar water heater subsidy

- Limits on less efficient vehicles
- Passenger modal shift
- Waste management
- Land use
- Escalating CO2 tax (Gibberd, 2015)

Three levels of intervention can be distinguished. These are at building, neighbourhood and urban level. Previous research indicated that in a hot country such as South Africa the most important factors at building level are building orientation and solar shading at appropriate times (Conradie, 2016a: 38-41). The general principle is that the sun should help to heat buildings in winter and should therefore be allowed to penetrate the building at this time. However in summer the building and especially the windows should be protected against direct solar radiation. The appropriate use of glass is closely related to the latter. Other factors such as building shape, building depth, insulation, opening areas, air tightness and correct use of mechanical systems are also important. It is also beneficial to use cool roofs and surfaces in its various forms such as green, blue and reflective cool roofs (typically white roofs). At neighbourhood and urban level the

Table 1: Quantified benefit of solar protection for various cities and towns in various climatic regions

City/ Town	Heating Degree and Cooling Degree Day category <sup>1</sup>							Solar protection (hours)	
	1 Medium Medium	2 Medium Low	3 Low High	4 Low Low	5 Low Medium	6 High Low	7 High Medium	2009	2100 <sup>2</sup> (A2)
Bloemfontein	■							1214	1899
Cape Town				■				729	1282
Durban					■			1436	2128
East London					■			871	1481
George				■				588	1128
Johannesburg	■							530	1532
Kimberley	■							1560	2165
Port Elizabeth				■				676	1588
Pretoria					■			1327	2109
ForumForum									
Pretoria Irene	■							963	1999
Roodeplaat					■			1361	2300
Upington					■			2017	2453
Polokwane (Pietersburg)					■			1268	2134

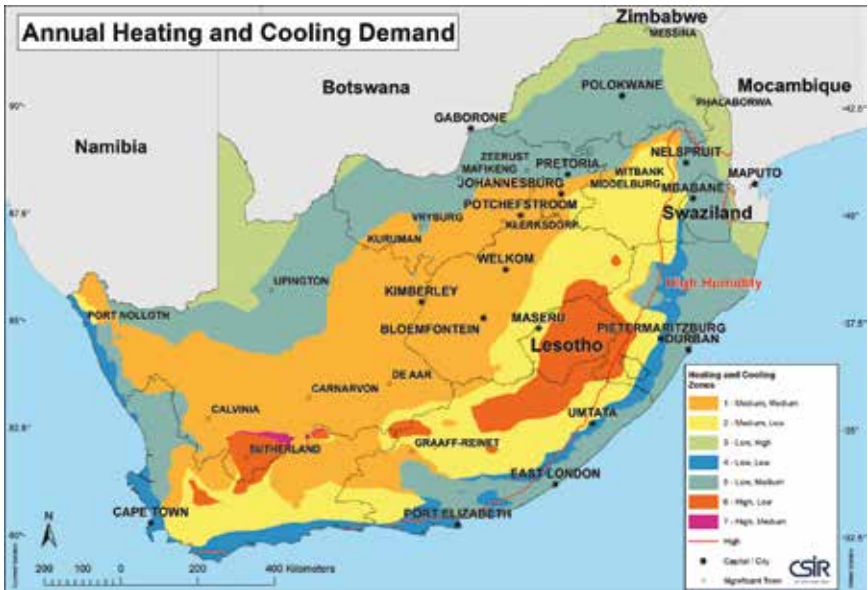


Figure 1: Combined heating and cooling low, medium and high (LMH)-zone map with summer and winter humidity lines for South Africa (Conradie et al., 2015a).

use of plants and street trees (Stoffberg et al., 2010: 9) are a good method to reduce the UHI due to a combination of shade and evaporative cooling (Stoffberg et al., 2010: 9).

Table 1 indicates the Heating and Cooling Degree Day category that the various cities and towns fall in. Table 1 should be read in conjunction with Figure 1. It also quantifies the number of hours that solar protection will be beneficial, currently and with an A2 climate change scenario. The latter figures were calculated by means of a bioclimatic analysis with Climate Consultant 6.0 using weather files generated by means of Meteororm v7.2.1. Table 1 therefore provides the baseline for the calculations performed later in the chapter.

### Urban heat islands

As city inhabitants know, it is quite often hotter in the city than surrounding rural areas. The term heat island is used because the city literally lies in a sea of cooler surrounding rural air. UHIs

are caused by the storage of solar energy in the hard urban construction materials that are quite often dark in colour (Table 2) and having a significant heat storage capacity. This energy is released during the night. The UHI effect was first observed by Luke Howard (1833: 2) in his accurate urban climate studies of 1806 to 1830. It is documented in his book *The climate of London*. At this stage Howard (1833: 2-3) had already observed a UHI effect of between 0.816 °C and 0.977 °C in London. The two maps of South Africa, included below, indicate that we are currently beginning to reach these levels. The amount of energy under the urban canopy can be expressed as follows (Howard, 1833: 8)1:

$$Q^* + Q_F = Q_H + Q_E + \square Q_S$$

1 In the forward of the IAUC edition of Howard's 1833 book.

Where:

$Q^*$  is the net radiation

$Q_F$  is the heat added by anthropogenic (human) activities

$Q_H$  is the sensible heat exchange

$Q_E$  is the latent heat exchange

$\square Q_S$  represents energy added to, or taken from, the urban fabric

The net radiation term can be broken up into solar (shortwave) and terrestrial (longwave) radiation.

$$Q^* = K^* + L^* \tag{2}$$

Research indicates (Sun et al., 2014: 174) that the UHI is the strongest at night under calm and clear skies. Under these conditions, those

terms requiring turbulence, i.e. ( $Q_H, Q_E$ ) are at a minimum and there is no solar radiation available. Further, with few exceptions,

$Q_F$  is generally insignificant. Under these conditions the formula can be simplified to:

$$L^* = \square Q_S$$

Abovementioned implies that when the urban temperature effect is the greatest, it is primarily a product of cooling driven by loss of

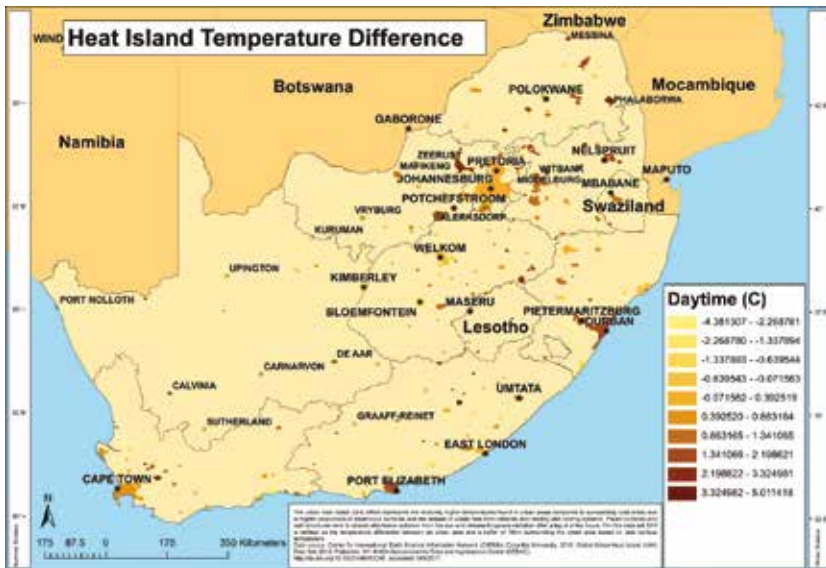


Figure 2: Daytime heat island temperature difference between an urban area and a buffer of 10 km surrounding the urban area based on land surface temperature. (Produced by CSIR based on data from Columbia University, 2016).



longwave radiation to the sky which is offset by the withdrawal of heat from construction material storage that was accumulated during the day.

In urban areas, the canopy surfaces (building walls and street surfaces) have limited exposure to the sky and consequently long-

wave cooling ( $L^*$ ) at night is significantly reduced. The urban construction materials are also impervious and dense. Such materials have a high thermal conductance and heat storage capacities, that were accumulated during the day and that is available for release at night.

Effective strategies that can be used to reduce UHI are cool roofs, green roofs, use trees/ plants and cool pavements or even roads. The use of more plants and trees in streets is a very effective

measure to reduce local exterior temperature with the combination of shade and evaporative cooling. (Van Hove et al., 2014: 52-53).

## Albedo

Albedo greatly affects the amount of diffuse radiation that will penetrate windows if buildings are surrounded by lightly coloured highly reflective surfaces. This could render carefully calculated solar protection devices less effective. It is therefore important that buildings are surrounded by surfaces of appropriate albedo and heat storage capacity. Albedo is also one of the most significant factors affecting pavement induced UHIs. Several studies have shown albedo's significant effect on air temperature and building energy usage. Albedo depends on the optical properties of the material constituents

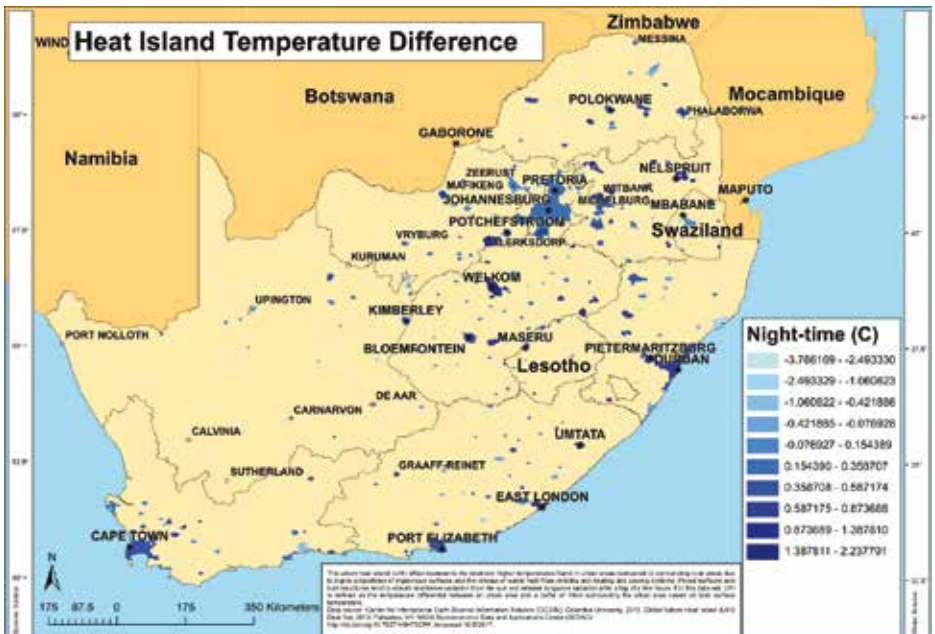


Figure 3: Night-time heat island temperature difference between an urban area and a buffer of 10 km surrounding the urban area based on land surface temperature. (Produced by CSIR based on data from Columbia University, 2016).

of the surface layer of the pavement, which can change over time or with additives (Sen et al., 2016).

The albedo can be calculated by means of an albedo meter such as a commercially available Hukseflux meter. Essentially it consists of two light meters, the one points upwards and the other downwards. The equipment measures the difference between the incident and reflected light from the surface being measured. This equipment is rather expensive and not readily available. An alternative method to measure albedo is to use a digital camera or smartphone to take a photograph of the surface together with a reference surface of known albedo such as an A4 sheet of white paper. This method has been described by Gilchrist (n.d.).

The author calculated the albedo values of ten common surfaces below (Table 2) by means of the integral digital camera in a smartphone. A standard A4 sheet of white office paper of known albedo (0.65) was placed alongside the surface to be measured (Gilchrist, n.d.). In formula (5) this is the factor used to calculate the absolute albedo. A photograph of both surfaces (office paper and surface to be measured) was then taken and loaded onto a computer. The ImageJ software available from the <https://imagej.nih.gov/ij/> website was used to compare the light and dark halves of the image. The following calculations were done:

$$Albedo_{(rel)} = \frac{B_{unknown}}{B_{reference}}$$

Where:

$B_{unknown}$  is the average brightness of an unknown surface

$B_{reference}$  is the average brightness of a known reference surface

Once the relative albedo has been calculated the absolute albedo can be determined by

means of the following calculation:

$$Albedo_{abs} = Albedo_{rel} \square 0.6$$

(5)

For example to calculate the albedo of a patch of Kikuyu lawn substitute the values as illustrated in Figure 4 into the formula 4.

$$Albedo_{rel} = \frac{8.620}{226.395}$$

(6)

Multiply the answer with the known albedo of a piece of white paper to determine the absolute albedo. Please refer to Table 2 where the absolute albedo as used in the example has been listed.

$$Albedo_{abs} = 0.2589 \square 0.6$$

(7)

$$Albedo_{abs} = 0.1683$$

(8)

It is interesting to note that although the Kikuyu grass has a low albedo of 0.1683 and therefore absorbs a significant amount of incident radiation, it doesn't heat up itself like the other surfaces that have a high heat storage capacity. Natural surfaces such as vegetation around buildings are therefore a very good way to keep surfaces cool and also avoid secondary indirect reflection causing glare and the transmission of additional heat into buildings.

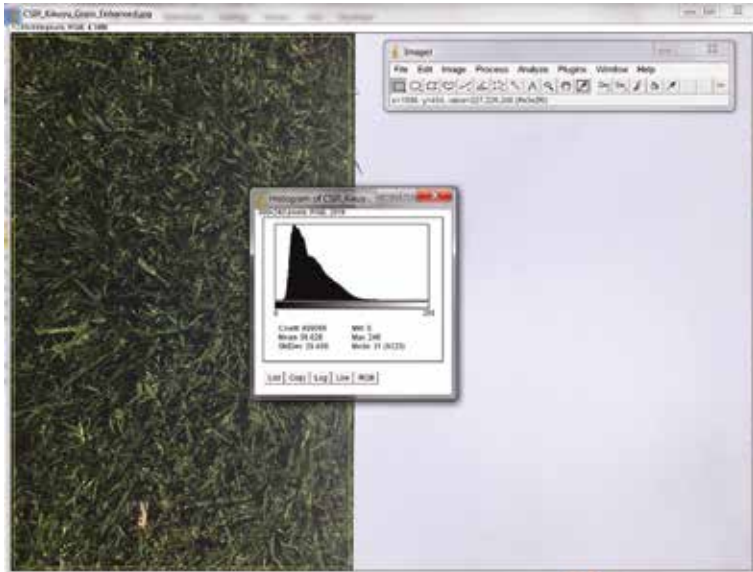


Figure 4: ImageJ software used to calculate the average brightness of each pixel contained in the yellow rectangle.

## The use of shading

One of the measures to ensure energy efficiency is the use of correctly engineered shading devices. The need for shading is the most important measure for protecting buildings from overheating when cooling is required (Kirimtat et al., 2016). Shading of windows and other building elements are very important to ensure a comfortable interior. In literature, numerous studies on shading devices integrated into buildings have been undertaken so far. Awareness of the use of shading devices in scientific studies started to develop since 1996 (Kirimtat et al., 2016). Simulation modelling became very efficient to study energy performance of buildings in the last few decades. There are various shading devices studied in literature. According to Kirimtat (2016) venetian blinds, mainly used in office buildings, are the most commonly studied. This is followed by fixed external louvres, roller shades and overhangs/ light shelves. Lesser studied types are vertical blinds/ fins, deciduous plants and

egg crates. A study in the tropical climate of Uganda indicate that shading strategies are very effective during the hottest periods of the year reducing the risk of extreme overheating by up to 52% (Hashemi et al., 2017). The research undertaken for this chapter indicate that with appropriate shading devices reductions in the incident kWh/m<sup>2</sup>/annum of 57.63% (Eastern façade), 52.45% (Western façade), 38.47% (Northern façade) and 26.67% is easily achievable. The roof can be protected in different ways for example by ventilated shading and cool roofs. In the former case 69.61% can be realised with a ventilated shading device placed 500 mm above the roof. A previous chapter (Conradie, 2016b) explored the benefits of using white or cool roofs.

There are essentially three different types of shadow recognized in astronomy, i.e. the umbra, penumbra and antumbra. These types are the three distinct parts of a shadow created by a light source such as the sun. These Latin terms

Table 2: Albedos of some common surfaces (Calculated by Author)

Material	Image	Albedo
Asphalt (Weathered)		0.2307
Brick (Nigel Iron Spot rockface)		0.3206
Ceramic paving tiles (Light coloured)		0.4076
Clay paving tiles (Red)		0.2249
Concrete (Weathered)		0.2930
Grass (Rough)		0.1880
Grass (Pennisetum clandestinum) (Kikuyu)		0.1683
Paving (Sand coloured concrete paving)		0.3134
Paving (Peach coloured clay)		0.3217
Sandy Soil (Red)		0.2471

are quite often used to describe shadows cast by celestial bodies, but they are also applicable in the built environment (Wikipedia, 2017).

The umbra is the innermost or darkest part of the shadow (Latin for “shadow”) where the light source is completely blocked by the occluding body. This would rarely be achieved in buildings even with properly engineered shading devices, because there is over and above the direct radiation also a significant amount of diffuse radiation especially if the surrounding pavement surfaces are highly reflective. The penumbra (from the Latin *paene* “almost, nearly”) is the region in which only a portion of the light source is obscured by the occluding body. This type of shade is what would most often be the case in buildings. The antumbra (from Latin *ante*, “before”) is the region from which the occluding body appears entirely contained within the disc/ shape of the occluding body (Figure 5). The antumbra is

useful when the designer wants reduce glare, but do not necessarily want to shade the specific space. The latter is applicable in the case of early morning or late afternoon sun especially in summer when the sun is at a very low angle above the horizon and especially on eastern, western and southern facades.

To be effective in buildings shading devices should provide at least penumbral shadow, but ideally umbral shadow at the right time. Antumbra shadow is not of much practical use or benefit as the observer is not actually shaded but just sees the shadow on an occluding object against the backdrop of light. However its main purpose is to reduce glare.

### Solar control

A model as illustrated below was created in Ecotect to calculate the figures in Table 3. Table 3 contains sub-headings for the eastern, western, northern and southern facades as well as the roof.



Figure 5: The three types of shadow are visible in this photograph of Stonehenge taken on 16 October 2012 at 10h38. The shadows cast on the ground are umbrae with very faint penumbrae outlines. The dark vertical backs of the standing stones are all antumbræ as they are seen against the late morning sun without the author being in their shade. The blocks are surrounded by an efficient low albedo surface (Author).

Under each of these headings two sub-columns list the amount of direct incident solar gain on the various surfaces without any solar protection (column U) and with a solar protection device (column P).

In Figure 6 the two northern overhangs are both 1 595 mm and the vertical facades 3 000 mm giving a total building height of 6 000 mm. The optimal overhang size has been precisely calculated using weather files from the Meteonorm v7.2 software for Pretoria Forum weather station based on a critical solar elevation angle above the northern horizon of 62° (Figure 8) to exclude the sun between 17 September and 25 March (Table 4). Table 4 indicates that the overhang sizes would need to be increased with climate change (Table 4). The vertical fins on the eastern and western facades have been placed at an angle of 30° to the façade and are 1 650 mm wide. It is assumed that the designer is going to use some glass on the eastern and western facades, otherwise the extensive solar protection would not have been necessary.

The analysis in Table 3 below clearly indicates the significant amount of direct incident solar gain on the various roof surfaces if they are not protected by means of shading or a cool surface. The unprotected roof values for the different cities are listed under the U-column of Roof. The P-column indicates the significant reduction in direct incident solar gain when the roof surface is protected by a shading device. In this case a second ventilated roof has been placed 500 mm above the concrete slab of the building. In the case of Bloemfontein this reduces the direct incident solar gain on the roof by 1 097 kWh/ m<sup>2</sup>/ annum. Other efficient protection methods such as a white or cool roof can be considered.

Figure 7: Examples of solar protection in South Africa. The building top left used vertical fins to protect a north-eastern façade. The building top right used small horizontal solar protection inappropriately on the western façade. Bottom left and right illustrate two types of solar shielding screens on the building northern facades.

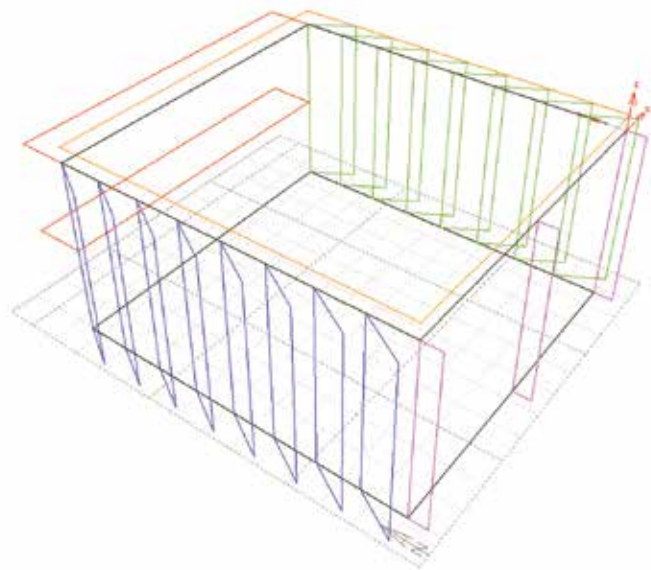


Figure 6: Ecotect simulation model used to simulate direct incident solar radiation and quantify the effect of solar protection devices.

	East		West		North		South		Roof	
	U	P	U	P	U	P	U	P	U	P
Bloemfontein	884	400	606	287	906	558	67	48	1565	468
Cape Town	776	350	519	246	786	462	57	39	1366	401
Durban	493	219	301	143	571	362	29	21	854	256
East London	554	249	372	176	654	418	35	24	964	301
George	672	301	453	213	745	461	46	31	1148	349
Johannesburg	759	340	501	238	748	461	57	41	1346	393
Kimberley	840	382	559	267	823	501	67	48	1457	434
Port Elizabeth	649	292	435	205	746	472	41	28	1130	351
Pretoria Forum	786	333	490	233	733	451 <sup>4</sup>	60	44	1349	410
Pretoria Irene	786	353	483	229	757	467	55	40	1362	399
Rondebosch	775	348	481	228	740	457	54	39	1361	397
Upington	949	435	665	315	959	574	74	54	1775	506
Polokwane (Pietersburg)	780	360	524	247	763	459	62	44	1474	410

Table 3: The amount of direct incident solar gain per roof surface in kWh/ m<sup>2</sup>/ annum. The values in column U is for unprotected surfaces and in column P for correctly engineered protected roof surfaces (Author).



Figure 7: Examples of solar protection in South Africa. The building top left used vertical fins to protect a north-eastern facade. The building top right used small horizontal solar protection inappropriately on the western façade. Bottom left and right illustrate two types of solar shielding screens on the building northern facades.

Figure 7 illustrate some examples of solar protection in South Africa. The top left building has vertical fins on a north-eastern façade. These fins are more suitable to protect eastern or western facades. In this case the designer made a compromise. The building top right inappropriately used narrow horizontal solar protection screens on the western façade. These are totally inefficient in the current location and are more suitable for the northern façade. The bottom left illustrates a building that has fine metal meshes to protect the eastern, northern and western facades. Screens are a very efficient solar protection measure however they exclude the sun in winter when it is really beneficial in passively heating the building and could also compromise the availability of natural daylight. The illustration bottom right is a different type of screen having the same advantages and disadvantages as the illustration bottom left.

The first set of simulations (Summarized in Table 3 under columns marked U) was to determine the amount of direct solar gain on the various unprotected building surfaces, normalized to kWh/ m<sup>2</sup>/ annum. These simulations were therefore undertaken without

any solar protection overhangs or fins. For the second set of simulations (Summarized in Table 3 under the columns marked P) overhangs, fins and a shaded roof were introduced.

The northern overhang used in these simulations was accurately calculated as for the central Pretoria (Pretoria Forum) weather station (Table 4). This overhang size was used for the other cities as well. To be more precise the actual solar optimal critical solar noon elevation angles for the other cities should also be determined by means of the method discussed in detail below and illustrated in Figure 8. From these angles the shaded and exposed period can be accurately determined as well as the correct size (horizontal projection width) of the northern horizontal

Figure 8: Calculated optimal critical solar noon elevation angles for the current climate (angles written in blue) and with climate change (angles written in red). The top row is for Roodeplaat (R1 and R2) (BSh), the middle row for central Pretoria (Pretoria Forum, F1 and F2) (Cwa) and the bottom row Irene (I1 and I2) (Cwb). The optimal solar angle at noon that determines the solar inclusion/ exclusion

Table 4: The critical angles and date ranges when solar protection should be applied to the northern facade of a building in the three climatic zones of Pretoria (Author)

	Cwb (Irene)		Cwa (Pretoria Forum)		BSh (Roodeplaat)	
Simulation period	2009	2100 <sup>5</sup>	2009	2100 <sup>5</sup>	2009	2100 <sup>5</sup>
Optimal critical northern solar noon elevation <sup>6</sup>	67°	57°	62°	56°	60°	55°
Estimated solar protection date range <sup>7</sup>	30 Sep to 12 Mar	4 Sep to 7 Apr	17 Sep to 25 Mar	1 Sep to 10 Apr	12 Sep to 30 Mar	29 Aug to 13 Apr
<b>Exposure/ Shaded (Hours)</b>						
<b>Warm/ hot &gt; 27 °C:</b>						
<b>exposed</b>	36	146	34	163	35	213
<b>shaded</b>	202	985	453	1 079	473	1 208
<b>Comfort &gt; 20 °C &lt;= 27 °C:</b>						
<b>exposed</b>	432	476	420	477	364	486
<b>shaded</b>	838	524	815	479	836	375
<b>Cool/ cold &lt;= 20 °C:</b>						
<b>exposed</b>	716	360	615	312	633	244
<b>shaded</b>	328	61	215	42	211	26



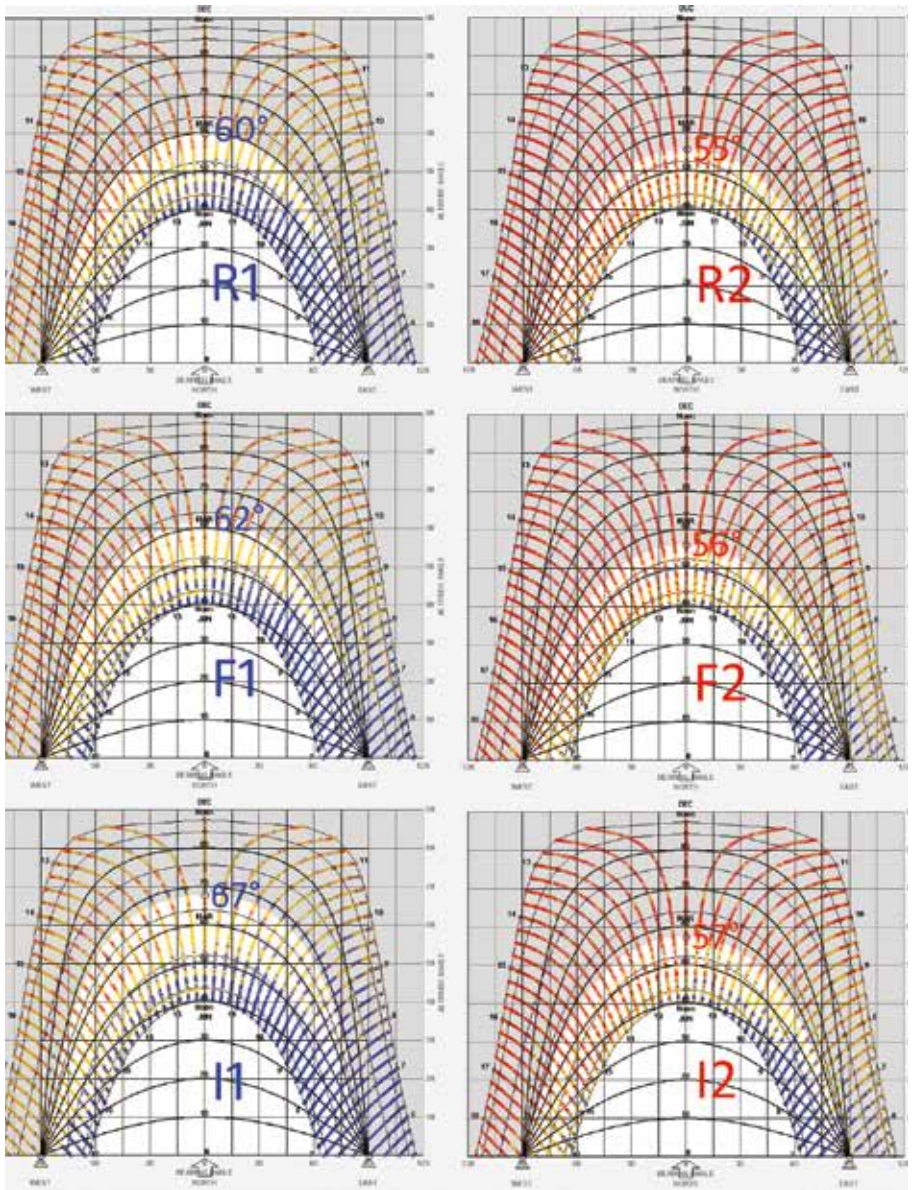


Figure 8: Calculated optimal critical solar noon elevation angles for the current climate (angles written in blue) and with climate change (angles written in red). The top row is for Rodeeplaat (R1 and R2) (BSh), the middle row for central Pretoria (Pretoria Forum, F1 and F2) (Cwa) and the bottom row Irene (I1 and I2) (Cwb). The optimal solar angle at noon that determines the solar inclusion/exclusion (depending on season) is indicated in each case (Conradie, 2017).

(depending on season) is indicated in each case (Conradie, 2017).

Glass is by far the weakest link in building design even if high performance Low-e glass is used (Conradie et al., 2015b: 112-121). Glass should therefore be well protected with shading devices during the overheated period. For example a PFG 20 mm Clearvue insulated Glass Unit with layers of Low-e, 4 mm + 12mm air gap + 4 mm clear glass gives a whole window U-value of 3.05, U-value at the centre of glass of 0.679 and a solar heat gain coefficient (SHGC) of 0.526. The discussion continues with an analysis of the northern overhang.

There are a number of methods that can be used to control solar penetration into buildings. The surfaces around a building or adjoining buildings determine the amount of direct and reflected radiation. In South Africa the northern facades should be protected by correctly sized overhangs. When designing north facing shading devices it is important to remember that the sun is not static. The designer should not design the device to shade only at solar noon. It needs to function during the late morning and early afternoon hours as well. By simply extending the device either side of the window a better degree of shading can be achieved. It is sometimes more economical to group the single windows than to provide individual windows with separate shading devices. Solar penetration into the eastern and western facades should be limited as far as possible by shifting the windows that they either face north or south (saw tooth façade) or use vertical adjustable fins or strategically placed vegetation. Even the southern façade needs protection as it receives a significant amount of solar radiation in summer when the sun rises in a southeasterly and sets in a southwesterly direction. Fins can be used to control this oblique radiation and light as well. The design is a function of the latitude, window size and fin depth/ frequency. Living solar protection such as deciduous trees and trellises with deciduous vines are very good shading devices. They are in phase with the thermal

year as they gain and lose leaves in response to temperature changes and will therefore automatically adapt to climate change.

A general rule of thumb is to make the overhang size such that the angle from the centre of the window sill through the edge of the northern overhang of a building the same as the solar noon elevation at the equinoxes for a given latitude. (equinox latitude approach). The SANS 204 (2011: 15-17) standard also describes a basic method to calculate the shading of the northern façade. It states that it should be capable of restricting at least 80% of summer solar radiation and if adjustable is readily operated either manually, mechanically or electronically by the building occupants.

To reduce energy use and to provide a comfortable interior the sun should be excluded during the hot summer months and included during the colder seasons. It is also important to realize that the seasons do not follow the purely geometrical solar positions such as the summer and winter solstices exactly. Although the winter solstice is on 21 June, the coldest period is normally later in July or even August. Similarly the hottest period in summer is not necessarily on summer solstice (21 December), but quite often only in January and February.

It is clear from the above that the hotter the climate gets, with more prevalent heat waves and climate change, the more important adequate shading and correct solar protection measures become to avoid unnecessary heat gains from the roof, that is a very large exposed area, and also the windows. To determine the optimal northern overhang size Climate Consultant 6.0 was used to calculate the critical noon northern solar elevation angles that can be used to calculate the width of the horizontal overhang for the current climate and then also with climate change using the previously generated set of weather files described above and used to calculate the shading diagrams in Figure 8.

The following method was used to determine the optimal northern overhang.

For illustrative purposes only Irene, Pretoria Forum and Roodeplaats were calculated (Table 4). An optimal horizontal northern overhang is assumed to be an overhang where there is a balance between the warm/ hot and cool/ cold periods of the year. In winter, solar radiation should be allowed to heat the interior of the building and in summer during the overheated period it should be excluded or shaded. The Climate Consultant 6.0 software has a "Sun Shading Chart" that can be used to accurately determine the balanced solar angle for Summer/ Autumn and Winter/ Spring. It has a special slider that the user can drag up and down corresponding to a northerly solar elevation angle of 0 to 90°. An interactive calculator on the top left of the software screen displays the number of warm/hot, comfort and cool/cold hours. By changing the shade angle an ideal angle can be established where there is a balance between the number of hours that shade is needed during the hot period and sun is needed during the cool period.

Angles written in blue and red on Figure 8 illustrates the results of the solar elevation calculations for the period from 21 December to 21 June, i.e. around the autumnal equinox. A similar set can be calculated for the period 21 June to 21 December, i.e. around the vernal equinox.

The next step was to determine from which dates the sun should be allowed and excluded. By means of a special solar angle calculator, that the author developed, based on algorithms from the North American, National Oceanic and Atmospheric Administration (NOAA) the actual autumnal and vernal calendar dates were determined using the critical angles previously calculated. The critical angles are where there is a balance between hot and cold periods. It is evident with climate change that the overhangs must not only be wider, but the period where solar protection will be required will become much longer. In practice it means that South Africa and Pretoria specifically will increasingly have a cooling rather than a heating problem. Table 4 above summarizes

the results of abovementioned angle and date calculations.

By using the techniques described above accurate overhangs can be calculated for the other cities and towns as well in a similar way that the angles were calculated for the three illustrative climatic regions of Pretoria.

## Conclusions

Many conclusions can be made from the article and some really interesting discoveries have been made.

The simulations clearly indicate the significant benefit of protecting the various facades of the building against direct solar gain, especially if these facades contain glass in windows or entire facades. It is also far more efficient to keep the direct and indirect solar radiation out of the building by proper ventilated shading devices, rather than trying to rely on expensive glass such as low-e glass that is not nearly as efficient. Modern simulation techniques make it possible design accurately engineered solar protection devices. In all cases the roofs need to be carefully designed as the direct incident radiation on the roof is much larger than any of the other surfaces. The most effective measures to control heat gains from the roof are cool or white roofs or alternatively a ventilated shading device such as the one illustrated in Figure 6 (floating horizontal surface with orange lines).

It is clear that in hot climates during heatwaves or with the expected climate change solar control is becoming increasingly important. It is reasoned and supported by simulation that this will mean increasing the amount of shade by increasing the overhang size on the northern façade. In practice this means keeping the roof as cool as possible and using correctly sized overhangs on the northern façade and appropriate solar protection on the other facades. It is important to realise that there are solar gains from the southern façade as well. For example in Pretoria solar gains from the southern façade cannot be entirely ignored because in summer the sun rises

well south of east and sets south of west. The research indicated that the northern overhang size will have to be increased to counter the overheating caused by climate change. The calculations in Table 4 clearly indicate that the shading period must also be increased because the overheated period is gradually increasing.

It was beyond the scope of this chapter to calculate this detail for all the other cities and towns. However similar techniques can be used. The sections of shade and albedo indicate that the solar protection devices need to provide good quality shade. The surrounding surfaces also need to be taken account of otherwise

indirect reflections from high albedo surfaces can neutralise the effects of carefully designed solar protection.

Although the article concentrated on solar protection other passive design aspects such as adequate ventilation and use of natural daylight should not be neglected. Improved ventilation will also help to promote evaporative cooling from the skin and in the process increase the general sense of comfort during the overheated period. From personal experience it is clear that the human body can withstand higher temperatures than previously thought if it had enough time to adapt or acclimatize.

## References

- The contribution of Sheldon Bole in the production of the heat island maps (Figures 2 and 3) is gratefully acknowledged.
- References
- Columbia University. 2016. Global Urban Heat Island (UHI) Data Set, 2013. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). <http://doi.org/10.7927/H4H70CRF>.
- Conradie, D.C.U. 2011. Maximising the sun. In: Green Building Handbook for South Africa, vol. 3, pp. 147-159.
- Conradie, D.C.U. 2013. Appropriate passive design approaches for the various climatic regions in South Africa. In: Green Building Handbook for South Africa, vol. 5, pp. 101-117.
- Conradie, D.C.U., & Szewczuk, S. 2015a. The use of glass in buildings – from crystal palace to Green building. In: Green Building Handbook for South Africa, vol. 8, pp. 112-121.
- Conradie, D.C.U., van Reenen, T. and Bole, S. 2015b. The Creation of Cooling Degree (CDD) and Heating Degree Day (HDD) Climatic Maps for South Africa. In Proceedings of the 5th CIB international Conference on Smart and Sustainable Built Environments (SASBE), University of Pretoria, Pretoria.
- Conradie, D.C.U. 2016a. Die invloed van klimaatverandering op die Suid-Afrikaanse stad en voorgestelde aanpassings. In: Town and Regional Planning, No. 68, May 2016, pp. 27-42. <http://dx.doi.org/10.18820/2415-0495/trp68i1.3>
- Conradie, D.C.U. 2016b. A sultry afternoon in a naturally ventilated office during the hottest summer on record, In Green Building Handbook for South Africa, Volume 10, pp. 48-60.
- Conradie, D.C.U. 2017. Bioclimatic Techniques to quantify mitigation measures for climate change with specific reference to Pretoria. In Proceedings of Smart and Sustainable Cities Seminar, 12-14 July, CSIR, Pretoria, South Africa.
- Gibberd, J. 2015. IUSS Health Facility Guides: Environment and Sustainability. <http://www.iuss-online.co.za/index.php/norms-standards/healthcare-environment/33-environment-and-sustainability>. Accessed on 28 March 2017.
- Gilchrist, G. n.d. A simple method to determine surface albedo using digital photography. Accessed on 23 October 2017. <http://vixra.org/pdf/1110.0035v1.pdf>
- Hashemi, A. and Khatami, N. 2017. Effects of solar shading on thermal comfort in low-income tropical

- Housing. In *Energy Procedia* 111 (2017), pp. 235 – 244.
- Howard, L. 1833. *The climate of London*. London: Harvey and Darton. (international Association for urban climate Edition).
- IPCC. 2000. *Summary for Policymakers: Emissions Scenarios*. Special Report of IPCC Working Group III of the Intergovernmental Panel on Climate Change. pp. 3-5.
- Kiritmat, A., Kundakci Koyunbaba, B., Chatzikonstantinou, I. and Sariyildiz, S. 2016. Review of simulation modelling for shading devices in buildings. In *Renewable and Sustainable Energy Reviews*, 53(2016), pp. 23–49.
- Riahi, K., Roa, S., Krey, V., Cho, C., Chirkov, V., Fisher, G., Kindermann, G., Nakicenovic, N., & Rafaj, P. 2011. RCP 8.5 – A scenario of comparatively high greenhouse gas emissions. In: *Climate Change*, 109, pp. 33-57. <https://doi.org/10.1007/s10584-011-0149-y>.
- Sen, S. and Roesler, J. 2016. Aging albedo model for asphalt pavement surfaces. In *Journal of Cleaner Production*, 117 (2016), pp. 169-175.
- SANS 204. 2011. South African National Standard. *Energy efficiency in buildings, Annexure A: Climatic zones of South Africa*. SABS Standards Division.
- Stoffberg, G.H., van Rooyen, M.W., van der Linde, M.J., & Groeneveld, H.T. 2010. Carbon sequestration of indigenous street trees in the city of Tshwane, South Africa. In: *Urban Forestry & Urban Greening*, 9, pp. 9-14. <https://doi.org/10.1016/j.ufug.2009.09.004>.
- Sun, Y. and Augenbroe, G. 2014. Urban heat island effect on energy application studies of office buildings. In *Energy and Buildings*, vol. 77, July 2014, pp. 171-179. <https://doi.org/10.1016/j.enbuild.2014.03.055>
- The International Bank for Reconstruction and development & World Bank. 2010. *Cities and climate change: An urgent agenda*. Washington DC: The International Bank for Reconstruction and Development/The World Bank, pp. 1-81.
- Van Hove, B., Blocken, B., van den Dobbelsteen, A., Spit, T. and Bosch, P. 2014. *Climate-proof cities – Final report*. Dutch research programme 'Knowledge for Climate', co-financed by the Dutch Ministry of Infrastructure and Environment. pp. 52-53.
- <https://en.wikipedia.org/wiki/Shadow>. Accessed on 20 October 2017.
- (Footnotes)
- 1 See Figure 1 below for the various heating and cooling zones.
- 2 Weather files with an A2 climate change scenario as defined by the IPCC (2000) has been used to calculate these values.
- 3 The northern façade overhang for Pretoria has been accurately calculated based on analyses with Climate Consultant 6.0, a solar angle calculator and simulations in Ecotect v5.60. Due to time constraints this hasn't been done accurately for the northern overhangs of other cities and towns reflected in the table. However the values for the other cities are indicative of what can be realised for the northern overhangs. The values for the east and west facades as well as the roof are accurate in all cases. In all cases including Pretoria, the fin sizes on the southern façade are illustrative and would require further research to calculate accurately.
- 4 A weather file with an A2 climate change scenario as defined by the IPCC (2000) has been used to calculate these values.
- 5 This is the critical northern elevation solar angle that determines the angle where solar protection should be applied or when the solar penetration should be allowed into the building depending on the time of year.
- 6 These dates define the period when the building should be protected against direct solar penetration on the northern façade. With climate change these date ranges become significantly longer and the overhang needs to be wider.



## Chapter 5

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# Climate Change: Implications for South African Building Systems and Components

— Jeremy Gibberd

## Introduction

Despite increasing awareness of climate change, there is little evidence of this being addressed in built environments in South Africa. Events such as flooding in Houston, USA, landslides in Free Town, Sierra Leone, and water shortages in La Paz, Bolivia and Cape Town in South Africa in 2017 demonstrate that it is increasingly urgent that built environments that are resilient to climate change impacts must be developed.

This chapter introduces climate change projections for South Africa and begins to determine the implications of these changes for buildings. Proposals are made on how buildings may be adapted to climate change and recommendations on further research and development are outlined.

## Methodology

Climate change projections are subject to uncertainty (Müller et al, 2014). Modelling methodologies and assumptions also vary and can be complex (Hewitson and Crane, 2006; Müller et al, 2014; Engelbrecht, 2016). Therefore while the range of modelling approaches are acknowledged, this study is based on one projection and scenario in order to focus on built environment implications of climate change.

The climate change projection selected for the study was carried out in 2017 and provides a high level of detail (8 x 8 km resolution) (Engelbrecht, 2016). The scenario selected is a low mitigation scenario (RCP 8.5) for the period 2021 – 2050 relative to 1961-1990. Representative Concentration Pathways (RCPs) are defined according to their contribution to atmospheric radiative forcing in the year 2100 relative to pre-industrial values. A RCP 8.5 therefore represents the addition to the earth's radiation budget as a result of an increase in GHGs of +8.5 W/m<sup>2</sup>. This scenario is presented in figures in the main body of the study.

Implications of climate change for built environments are ascertained through an

analysis of projections in different regions. Measures to address climate change are identified through a literature review. Examples provided in the study are drawn from residential, health and education sectors as these are some of the most vulnerable to climate change.

## Climate change

Climate change is now considered as one of the most important global issues facing the world today and increasingly sophisticated climate models are being developed to project climate changes (Hamin and Gurran, 2009; Guan, 2009).

Designing climate-resilient architecture requires an understanding the climate change projections at the building site. As buildings usually have a lifespan of at least 50 years, these projections need to cover the next 50 years (Guan, 2009).

Climate change projections for South Africa have been generated for 2030, 2050 and 2100. This indicate that while there a significant differences across South Africa, some broad trends can be described:

- Hotter temperatures: Temperature increases of 1 to 2.5°C in the southern coastal areas and 3°C in the northern areas of South Africa are projected for the period 2021 to 2050, relative to temperatures in the period 1961 – 1990.
- Minimum temperatures: Minimum temperatures are projected to increase by 2 to 3 °C for the period 2021 – 2050, relative to the period 1961 -1990.
- Very hot days: An increase in very hot days is projected for the period 2021 – 2050, relative to 1961 – 1990.
- Changes in rainfall: Increases in annual rainfall are projected in the central interior and east coast, while reductions are expected in the western interior and the north-eastern parts of South Africa in the period 2021-2050, relative to the period 1971 – 2000.
- Extreme rainfall events: Extreme rainfall events are projected to increase in

frequency in the central interior and east coast for the period 2021-2050, relative to the period 1961 – 2000. For the period 2070-2099, relative to the period 1961 – 2000, reductions in these events are projected for Lesotho and Kwa-Zulu Natal Midlands areas.

- Increased wind speeds: Wind speeds are projected to increase in the northern interior regions of South Africa and decrease in other regions for the period 2021-2050, relative to the period 1961 – 2000 (Engelbrecht, 2016).

## The implications of climate change for buildings

Better understanding of climate change implies a corresponding improvements in built environment responses. Addressing climate change in buildings requires a balance between mitigation and adaption strategies. Climate change mitigation strategies aim to reduce current and future greenhouse gas emissions in order to slow down and ultimately stop climate change. Climate change adaptation strategies aim to adjust to unavoidable changes that will in occur and minimize their negative impacts (Hamin and Gurran, 2009; IPCC, 2007)

These strategies can be in conflict. For instance, building adaptations to cope with increased wind speeds, storms and floods predicted by climate change projections may require additional materials and structure which

have additional carbon emissions associated with their manufacturing and construction, thereby contributing to climate change. However synergies can be found. For examples, shifting to decentralized renewable energy generation reduces both carbon emissions (mitigation) as well as the risk of widespread power outages associated with severe storms (adaptation) (Hamin and Gurran, 2009). Where possible, this type of 'win-win' approach must be pursued.

In proposing measures to address climate change, uncertainties associated with projection models should be acknowledged. Proposals should, therefore, aim to yield benefits even in the absence of, or delay in, climate change (no regret), be adaptable and have margins that account for uncertainty (Hallegatte, 2009)

The capacity to adapt to future climate change is referred to as resilience. Resilience describes the ability to accommodate or adapt to, changes associated with climate change (Hamin and Gurran, 2009). The International Panel on Climate Change describes resilience as the capacity to absorb disturbance and change, while still retaining the same basic structure and functioning (IPCC, 2007). This implies an increased emphasis on flexibility and adaptability in building system and component design (IPCC, 2007). Research in this area has

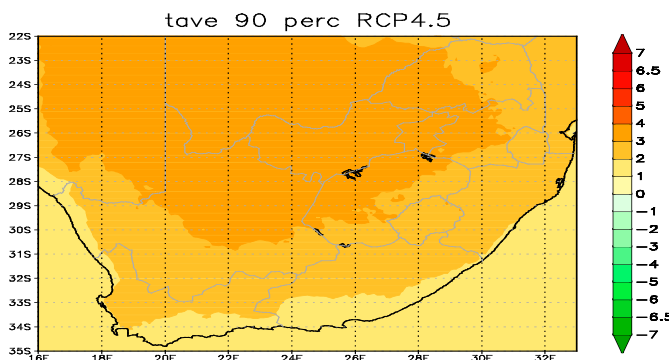


Figure 1. Projected change in the annual average temperature (°C) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).



interesting implications for buildings and can provide designers with a rich palette of tools to develop more resilient buildings, systems and components (Gibberd, 2017; Gibberd 2017a).

### Higher average temperatures

Temperature increases of 1 to 2.5°C in the southern coastal areas and 3°C in the northern areas of South Africa are expected for the period 2021 to 2050, relative to temperatures in the period 1961 – 1990. This trend continues in the period 2070 to 2099 and average temperatures are projected to increase by a further 2 - 3°C over the southern coastal regions, with the increases of 4°C up to 7°C projected for the interior (Engelbrecht, 2016). Figure 1 shows these increases in annual average temperature for the period 2021-2050 relative to 1961 - 1990.

Higher average temperatures will result in temperatures within unconditioned buildings increasing. In particular, this effect will be experienced most acutely in buildings that have limited or no insulation and cooling systems, such as school buildings, clinics and low-cost housing (Gibberd and Motsatsi, 2013). Environments around buildings will also become hotter. This will affect conditions for people who work outside such as construction and agricultural workers. It will also affect children who play and exercise outside during school breaks and during school sports activities.

A range of implications of higher average temperatures can be envisaged for buildings, building systems and components. Higher temperatures will mean that aspects of existing and proposed designs may no longer be suitable. Increased temperatures will result in existing cooling equipment struggling to accommodate higher heat loads. Insufficient solar control, insulation and passive cooling strategies will mean that internal conditions in buildings become uncomfortably hot. Higher temperatures will also affect the lifespan of components and materials that

have been designed and manufactured for lower ambient temperatures.

Addressing these implications is complex and should take into account detailed climate projections and local circumstances. The following generic measures may be considered to address increased average temperatures:

- **External hard surfaces:** The extent of external hard surfaces around buildings should be minimised. If this is unavoidable, lighter coloured materials should be used. This will help reduce the extent to which heat is absorbed and accumulates in urban spaces to produce what is known as the urban heat island effect (Zuo et al, 2014; Santamouris, 2015)
- **Trees and shading:** Shading should be provided around buildings and in areas where external spaces are occupied, such as school playgrounds. This reduces temperatures around buildings and provides cooler external spaces that can be used on hot days (Zuo et al, 2014; Wong & Chen, 2009).
- **Cool roofs:** Specifying lighter colours on external faces of roofs and walls can be used to reduce the heat absorption through these surfaces and therefore heat gain in the building (Cotana et al, 2014).
- **Insulation:** Increasing insulation in the building envelope reduces heat gains in buildings. In conditioned buildings, additional insulation throughout the building envelope can help reduce heat gain. In passive buildings, additional insulation can be used in the roof and applied selectively to the building envelope to reduce heat gains and improve the effectiveness of passive strategies (Saman et al, 2013).
- **Passive cooling:** Passive cooling refers the cooling of buildings to improve the indoor thermal comfort with low or no energy consumption and associated carbon emissions. Passive cooling strategies include cross ventilation, evaporative cooling and

night-time cooling. Cross ventilation is suitable for locations with breezes, such as coastal regions, whereas night-time cooling is suitable for locations with high diurnal ranges, such as the interior of the country (Karimpour et al, 2015; Peacock et al, 2010).

- Mechanical cooling: Mechanical cooling systems can also be used to reduce temperatures in buildings. In housing, clinics and schools, ceiling fans powered by photovoltaic panels may be an effective means of introducing cooling at low cost while minimising associated carbon emissions.

year for the entire northern and western interior of the South Africa (Engelbrecht, 2016). Figure 2 shows projected change in the number of very hot days for the period 2021-2050 relative to 1961 - 1990.

A range of implications of very hot days can be envisaged for buildings, building systems and components. Very hot days mean that existing cooling equipment in buildings may not be able to accommodate increased heat loads, especially when hot days occur consecutively. In buildings with insufficient insulation and inadequate passive cooling strategies, internal conditions in buildings will become uncomfortably hot (Gibberd and Motsatsi, 2013). Very hot conditions over long periods may also affect the lifespan of components and materials that have been designed for cooler temperatures.

Accommodating very hot days in buildings is complex and should take into account detailed climate projections and local circumstances. In the first instance, the measures described for increased average temperatures (above) may be used to address hotter conditions. However, on very hot days, the following measures

### Very hot days

Very hot days are defined as days when the maximum temperature exceeds 35°C. For the period 2021 – 2050 relative to 1961 – 1990 very hot days are projected to increase by 40 to 60 days per year in areas of the Limpopo valley. This will be higher in northern parts of the Northern Cape and North West provinces, where the increases may be up to 70 days per year. During the period 2070 – 2099 very hot days are projected to increase to 80 or more days per

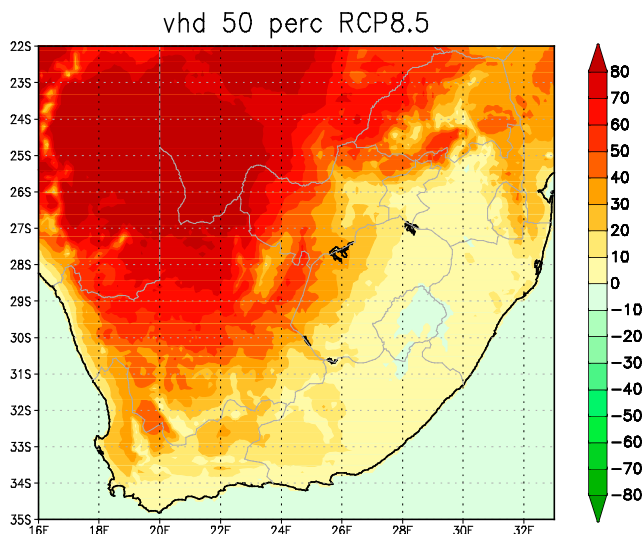


Figure 2. Projected change in the annual average number of very hot days (units are days per grid point per year) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

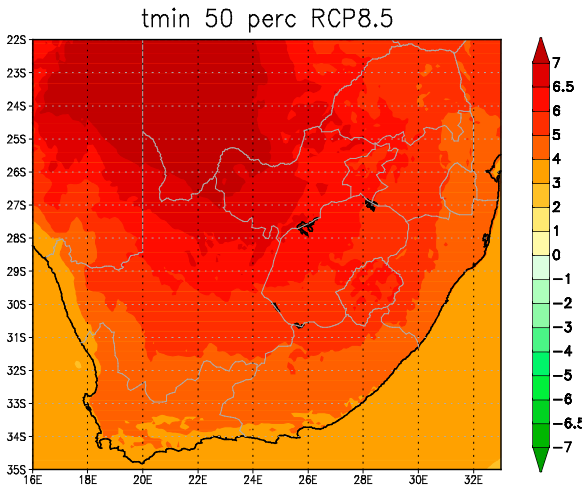


Figure 3. Projected change in the annual average minimum temperature (°C) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

related building and personal adaptation can be implemented:

- Building adaptations: Building adaptations to reduce heat stress include the provision of drinking water points, shading of all glazing in building envelopes, the provision of spaces around the buildings such as interior rooms, courtyards and rooftops which can be moved between to provide cooler spaces at different times of the day and night (Hatvani-Kovacs et al, 2016; Baker & Standeven, 1996).
- Personal adaptations: Personal adaptation to reduce heat stress include drinking water, spending more time indoors or in shaded areas, wearing loose clothing and planning the day to stay out of the heat and to move between cooler parts of the building (Krecar et al, 2014; Hatvani-Kovacs et al, 2016; Saman et al, 2013)

### Minimum temperatures

Minimum temperatures are projected to increase by 2 to 3°C for the period 2021 – 2050, relative to the period 1961-1990. For the period 2071 to 2099 minimum temperatures are projected to an increase of more than

4°C in much of the interior with areas of the northern interior potentially experiencing increases exceeding 7°C. Figure 3 shows projected change in annual average minimum temperatures for the period 2021-2050 compared to the period 1961-1990.

Increasing minimum temperatures will result in reduced risk of very cold temperatures in buildings. The potential for water freezing in pipes and dangerous icy conditions on external surfaces will also be reduced. Increasing minimum temperatures will reduce the effectiveness of night-time cooling as a passive environmental control strategy in buildings.

However, higher minimum temperatures will also reduce heating loads for mechanical heating systems in buildings and mean that the requirement for heating is reduced or even eliminated in some locations. Indoor temperatures in buildings without insulation and inadequate passive heating strategies will be higher in winter, resulting in improved levels of comfort in winter.

Higher minimum temperatures mean that winter performance requirements of building components and equipment will be reduced. Therefore, there may be reduced performance

requirements for systems and equipment designed to cater for cold and extremely cold conditions such as heating systems, insulation, double or triple glazing, and thermally broken window and door frames. However, it should be noted that some of these systems and equipment also help reduce heat gain under hot conditions and therefore may be appropriate for adapting to very hot days. Increasing minimum temperatures have the following implications for buildings:

- Insulation: Increasing minimum temperatures mean that it is easier to achieve comfortable internal conditions during winter. Climate change, however, may mean that it may also be more difficult to keep internal conditions comfortable during summer as higher temperatures are experienced. This will change the way insulation is designed and specified in order to cater for increased minimum temperatures, increased average temperatures and very hot days. A responsive approach which takes into account local circumstances and thermal mass rather than a 'blanket' approach in the application of insulation (which may lead to overheating) is likely to lead to the best results (Gibberd, 2009; Porritt et al, 2013; Ren et al, 2014).
- Heating: Heating requirements are likely to be reduced with increasing minimum temperatures. However, increased average temperatures will also result in increasing

cooling requirements. This shift will need to be addressed in the design and specification of heating and cooling equipment.

- Passive design: Increased minimum temperatures will result in the reduced cooling potential of strategies such as night-time cooling. Passive design strategies will, therefore, need to be revised for projected climates.

### Changes in rainfall

Increases in rainfall are projected in the central interior and east coast, while reductions are expected in the western interior and the north-eastern parts of South Africa in the period 2021 – 2050, relative to the period 1971 – 2000. Over the period 2070 to 2099 relative to the period 1961 to 1990 rainfall projections are expected to follow a similar pattern to the earlier period, however, there is also a possibility that rainfall decreases over the central interior and east coast of South Africa. Figure 4 shows changes in annual average rainfall for the period 2021 – 2050 compared to 1961 – 1990.

Reductions and increases in annual rainfall have a number of implications for buildings, building systems and component. Reductions in rainfall in cities and settlements will mean that these will be more likely to be affected by water shortages as water supplies from dams, rivers and boreholes are more likely to be depleted.

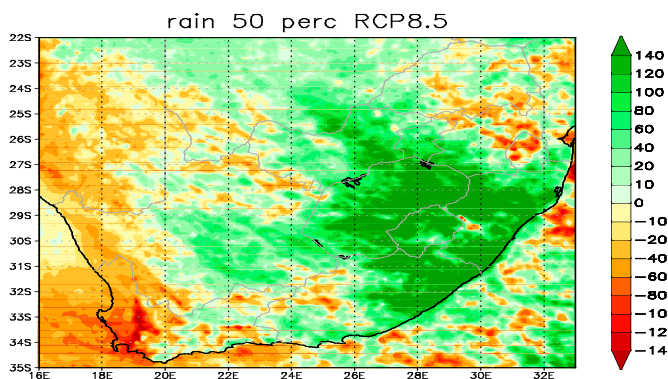


Figure 4. Projected change in the annual average rainfall totals (mm) over South Africa at 8 km resolution, for 2021-2050 relative to 1961-1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

Reductions in rainfall will diminish the moisture available for plants and therefore influence the type of plants that will grow leading to the establishment of more drought-resistant species.

More rainfall will increase moisture around buildings. This will result in increased dampness and moisture-related problems in poorly constructed buildings and buildings with insufficient damp and water proofing. Where not addressed, these problems can lead to rapid deterioration of the building fabric and health problems, such as asthma (Bornehag et al, 2004; Fisk et al, 2007). Wetter conditions also favour different species and lead to changes in the type of plants and trees that will thrive in particular environments.

The following generic building adaptations can be applied to address changes in annual rainfall:

### **Areas with decreasing annual rainfall**

- **Water efficient fittings:** Highly efficient water fittings such as low-flow showerheads and taps should be used to reduce water consumption (Gibberd 2009a). This can be complemented by water metering and leak detection systems that ensure that water consumption is monitored and consumption reduced.
- **The use of water:** Water uses that are not strictly necessary should be discouraged. Examples include baths (showers should be used instead), swimming pools and large ornamental lawns and ponds. In highly water-stressed areas alternatives to the use of water to flush toilets and to wash objects such as cars should be investigated. In these cases, dry sanitation and dry cleaning methods may be appropriate (Gibberd, 2009a).
- **Grey water systems:** Grey water systems can significantly reduce water consumption in building types where grey water from activities such as hand washing and showers is available in adequate quantities. Grey

water can be used to flush toilets or irrigate plants, reducing or avoiding the use of mains potable water for these purposes (Gibberd, 2009a).

- **Rainwater harvesting:** Increased use of rainwater harvesting systems can be used to store rainwater enabling this to be available during dry periods (Gibberd 2009a, Gibberd 2015). This reduces the pressure on mains water supplies and provides a buffer in case of water shortages.
- **Planting schemes and landscaping:** Specification of plants, such as trees, with a higher tolerance for drier conditions, will ensure that these survive drier conditions. Water-scarce landscaping management techniques such as mulching and planting species that have the same water requirements together (hydro zoning) will help plants grow in drier conditions.

### **Areas with increasing annual rainfall**

- **Water proofing details:** To avoid potential dampness and moisture-related problems in buildings, increased attention to waterproofing in buildings will be required. This includes ensuring that the correct damp-proof membrane (DPM) and damp-proof course (DPC) products are used and that these are installed correctly. In addition, additional care will be required to ensure that roofs and exposed parts of the building are water tight and leaks are avoided. This means careful selection and specification of components, construction by trained contractors and effective supervision and testing of completed installations.
- **Sustainable Urban Drainage Systems (SUDS):** Increasing annual rainfall will heighten the risk of flooding in urban areas. This can be addressed by reducing the extent of impervious surfaces in urban areas and increasing areas of gardens and planted beds where runoff can be directed and absorbed. Components, such as permeable paving, can also be used to allow runoff to

replenish groundwater or be stored and used for irrigation and other purposes. Storm water can be reduced from sites through landscaping techniques which use filter strips, swales, and ponds to retain and store runoff on site.

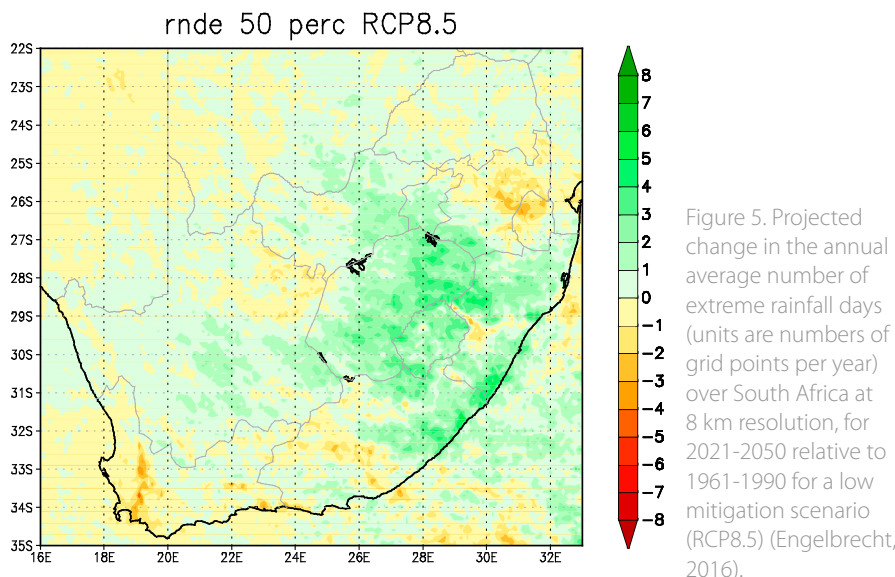
Buildings can be adapted for extreme rainfall. These can include measures for increased annual rainfall (as above) as well as the following for more extreme rainfall:

- Roof design and details: Roofs and rainwater goods have to be specifically designed for projected rainfall events. This may mean revising rainwater system designs to provide for larger volumes of water and include higher capacity and more numerous outlets, gutters and downpipes. In addition, similar considerations will be required to ensure that increased volumes of rainwater generated can be stored or disposed of safely.
- Storm water design: Extreme rainfall events will substantially increase volumes of surface runoff and the potential for flooding. This can be addressed by controlling the area of surfaces generating runoff and by ensuring appropriate means, such as retention and detention ponds, are in place and capable of managing runoff volumes.
- Flooding: In buildings in low lying areas where flooding is possible a number

### Extreme rainfall events

Extreme rainfall events are defined as events when 20mm of rain occurs over an area of 64km<sup>2</sup> over 24 hours. Over the period 2021 to 2050 relative to 1961 – 2000 the number of extreme rainfall events is projected to increase in the interior of South Africa. However, over the period 2070 to 2099, the number of extreme rainfall events is projected to decrease. Figure 5 shows these changes for the period 2021-2050 relative to 1961 - 1990.

Projected increases in extreme rainfall days have a number of implications for buildings. Vey heavy rainfall on roofs, if not disposed of quickly, can damage rainwater goods, roofs and cause structural collapse. Storm water can also accumulate leading to flooding of low lying buildings and infrastructure.



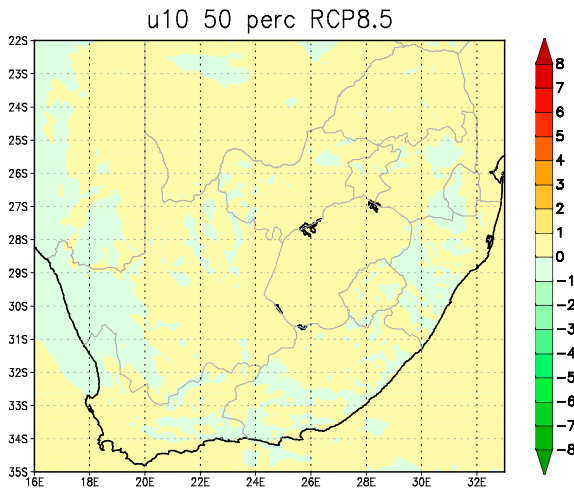


Figure 6. Projected change in the annual average wind speed (m/s) over South Africa at 8 km resolution, for 2021–2050 relative to 1961–1990 for a low mitigation scenario (RCP8.5) (Engelbrecht, 2016).

adaptations can be considered. Ground floor levels can be raised to reduce or avoid flooding the interior of buildings. Building layouts can be designed to ensure that water flows around and away from buildings and that ‘damming’ that may cause structural collapse is prevented. The design and maintenance of storm water drainage systems should ensure that blockages caused by detritus that can cause flooding is avoided. Expensive or delicate equipment and goods may be located higher up in buildings to reduce the possibility that this is damaged by flooding. In addition, building materials that are less prone to damage by moisture and flooding may be specified to avoid the need for large-scale replacement of components and elements in the building when flooding occurs.

### Increased wind speeds

For the period 2021 to 2050 relative to 1961 to 1990 increased wind speeds are projected along the east coast and over high altitude areas of the southwestern Cape as well as the eastern and southern escarpment. Wind speeds in the southern interior are projected to

decrease, while they are projected to increase in the northern interior. Figure 6 shows the projected changes in annual average wind speeds changes for the period 2021–2050 relative to 1961–1990.

Projected increases in average wind speeds have a number of implications for buildings. Increased wind speeds result in additional stress on exposed elements such as towers and overhanging sections of roof. If not catered for in design and construction, this additional stress can result in damage, such as roof sheeting becoming detached. Changes in wind speed will also affect energy generation potential in wind turbines.

Buildings can be adapted to address projected changes in wind speeds in the following way:

Wind loadings: Further investigation of projected wind speeds should be carried out. If these show that there are likely to be substantial increases, guidance on wind loadings in buildings should be reviewed and revised if necessary. Aspects that may be affected include guidance on wind loading in roofs, walls and large areas of glazing. Adaptations may include additional structural

and fixing elements to compensate for increased loadings.

## Conclusions and recommendations

Projections for South African indicate that there will be significant changes in climate over the period 2021 – 2099 relative to the period 1961-1990. These changes include higher average temperatures, higher minimum temperatures, increases in the number of very hot days, changes in rainfall, increases in extreme rainfall events, and changes in average wind speeds. There are significant implications for buildings and building systems and components of these changes.

As buildings are generally designed to be used for at least 50 years it is important that buildings, and their systems and components, are designed to accommodate projected changes that may occur over their lifespan. Climate change has meant that many aspects of buildings have to be reconsidered and new approaches, systems and

components have to be developed. A selection of initial considerations is discussed.

The current onset of climate change means that building, building systems and component designs need to be urgently reviewed, and where necessarily, adapted to changing climate conditions. This can be supported by the following actions:

**Climate change projections:** The most important climate change projections for building, building systems and component design should be developed so that implications can be understood at a local level.

**Design guidelines:** Design guidelines based on climate change projections should be created to provide guidance on the design of buildings, building systems and components. Current standards and regulations: Current building, building system and component standards and regulations should be reviewed and adapted as necessary in the light of climate change projections.

## References

- Baker, N. and Standeven, M., 1996. Thermal comfort for free-running buildings. *Energy and Buildings*, 23(3), pp.175-182.
- Bornehag, C.G., Sundell, J., Bonini, S., Custovic, A., Malmberg, P., Skerfving, S., Sigsgaard, T. and Verhoeff, A., 2004. Dampness in buildings as a risk factor for health effects, EUROEXPO: a multidisciplinary review of the literature (1998–2000) on dampness and mite exposure in buildings and health effects. *Indoor air*, 14(4), pp.243-257.
- Cotana, F., Rossi, F., Filipponi, M., Cocchia, V., Pisello, A.L., Bonamente, E., Petrozzi, A. and Cavalaglio, G., 2014. Albedo control as an effective strategy to tackle Global Warming: A case study. *Applied Energy*, 130, pp.641-647.
- Engelbrecht, F., 2017. Detailed projections of future climate change over South Africa, CSIR Technical Report.
- Fisk, W.J., Lei-Gomez, Q. and Mendell, M.J., 2007. Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. *Indoor air*, 17(4), pp.284-296.
- Gibberd, J., and Motsatsi, L., 2013. Are Environmental Conditions in South African Classrooms Conducive for Learning?, SB13 Southern Africa, 15-16 October 2013, Cape Town, South Africa.
- Gibberd, J. 2009. Building Envelope, Chapter in the Green Building Handbook Volume 1, Alive 2 Green Publishers, ISBN 978-0-620-45067-6
- Gibberd, J. 2009a. Water Conservation, Chapter in the Green Building Handbook Volume 1, Alive 2 Green Publishers, ISBN 978-0-620-45067-6
- Gibberd, J., 2015. Rainwater harvesting playing a valuable role in increasing the resilience and



sustainability of water supply, Sustainable Water Resource Handbook Volume 6, Alive 2 Green Publishers

- Gibberd, J., 2017. Social Resilience in Urban Areas, 11th Built Environment Conference, Durban South Africa, 6 – 8th August 2017 Durban, South Africa.
- Gibberd, J., 2017a. Water Resilience in Urban Areas, 11th Built Environment Conference, Durban South Africa, 6 – 8th August 2017 Durban, South Africa.
- Guan, L., 2009. Preparation of future weather data to study the impact of climate change on buildings. *Building and environment*, 44(4), pp.793-800.
- Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change. *Global environmental change*, 19(2), pp.240-247.
- Hamin, E.M. and Gurrán, N., 2009. Urban form and climate change: Balancing adaptation and mitigation in the US and Australia. *Habitat international*, 33(3), pp.238-245.
- Hatvani-Kovacs, G., Belusko, M., Skinner, N., Pockett, J. and Boland, J., 2016. Heat stress risk and resilience in the urban environment. *Sustainable Cities and Society*, 26, pp.278-288.
- Hewitson, B.C. and Crane, R.G., 2006. Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. *International Journal of Climatology*, 26(10), pp.1315-1337.
- IPCC, 2007. *Climate change 2007: Synthesis report, fourth assessment report*. Cambridge: International Panel on Climate Change and Cambridge University Press.
- Karimpour, M., Belusko, M., Xing, K., Boland, J. and Bruno, F., 2015. Impact of climate change on the design of energy efficient residential building envelopes. *Energy and Buildings*, 87, pp.142-154.
- Ren, Z., Wang, X. and Chen, D., 2014. Heat stress within energy efficient dwellings in Australia. *Architectural Science Review*, 57(3), pp.227-236.
- Krecar, I.M., Kolega, M. and Kunac, S.F., 2014. The Effects of Drinking Water on Attention. *Procedia-Social and Behavioral Sciences*, 159, pp.577-583.
- Lapisa, R., Bozonnet, E., Abadie, M.O. and Salagnac, P., 2013. Cool roof and ventilation efficiency as passive cooling strategies for commercial low-rise buildings—ground thermal inertia impact. *Advances in Building Energy Research*, 7(2), pp.192-208.
- Müller, C., Waha, K., Bondeau, A. and Heinke, J., 2014. Hotspots of climate change impacts in sub-Saharan Africa and implications for adaptation and development. *Global change biology*, 20(8), pp.2505-2517.
- Peacock, A.D., Jenkins, D.P. and Kane, D., 2010. Investigating the potential of overheating in UK dwellings as a consequence of extant climate change. *Energy policy*, 38(7), pp.3277-3288.
- Porritt, S., C. Cropper, P., Shao, L. and I. Goodier, C., 2013. Heat wave adaptations for UK dwellings and development of a retrofit toolkit. *International Journal of Disaster Resilience in the Built Environment*, 4(3), pp.269-286.
- Saman, W., Boland, J., Pullen, S., de Dear, R.J., Soebarto, V., Miller, W.F., Pocock, B., Belusko, M., Bruno, F., Whaley, D. and Pockett, J., 2013. A framework for adaptation of Australian households to heat waves. *National Climate Change Adaptation Research Facility*.
- Santamouris, M., 2014. On the energy impact of urban heat island and global warming on buildings. *Energy and Buildings*, 82, pp.100-113.
- Wong, N.H. and Chen, Y., 2008. *Tropical urban heat islands: climate, buildings and greenery*. Routledge.
- Zuo, J., Pullen, S., Palmer, J., Bennetts, H., Chileshe, N. and Ma, T., 2015. Impacts of heat waves and corresponding measures: a review. *Journal of Cleaner Production*, 92, pp.1-12.

# Chapter 6

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## Strengths and limitations of the transport category in the green star South Africa rating system

— Mokonyama Mathetha & Nkosi Muzi



## Abstract

The chapter evaluates the strengths and limitations of the Green Star South Africa's rating scheme in respect of its transport environment category. The evaluation is necessary, among other things, to guide decision makers on the interpretation of the tool's outcomes for general transport planning. Using office buildings that have already been rated in Gauteng Province as case studies, and comparison of the tool with similar other tools in the world, it was found that while the tool evaluates the right dimensions, it remains fundamentally flawed by disregarding the network-based nature of transport services and operations, as well as the travel behaviour of building users. Prospects for improving the calculator are discussed. The role of transport planning authorities to support Green Building Council South Africa and developers in this regard is seen as critical.

## Introduction

The Green Star South Africa rating scheme is one of the many such schemes in use globally, including the Green Mark Scheme (GMS) in Singapore, Leadership in Energy and Environmental Design (LEED) in the United States, Building Research Establishment Environmental Assessment Method (BREEAM) and Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, and Green Building Council of Australia Green Star (GBCAGS) in Australia. Haddad (2017) identifies 17 such schemes in the world. However, BREEAM, LEED and Green Star Australia have found the widest application (Roderick et al., 2009). Collectively, these schemes have the primary objective of measuring and reporting on the performance of buildings in terms of the ability to minimise their lifecycle energy consumption, greenhouse gas emissions and water consumption. For example, a green building has, potentially, half the energy requirements of a conventional building (DEA, 2009).

A broader definition of a green building requires a triple bottom-line approach, namely environmental, social and economic considerations (Illankoon, et al., 2017; Zuo and Zhao, 2014). This ties with the concept of sustainable transport, which is characterised by a transport system that promotes (i) liveable streets and neighbourhoods, (ii) environmental protection, (iii) equity and inclusion, (iv) health and safety, and (v) support of an efficient and vibrant economy (Castillo and Pitfield, 2010). Nonetheless, social and economic considerations are rarely included in the ratings (Zuo and Zhao, 2014; Doan, et al., 2017), notably in LEED and Green Star Australia (Xia et al. 2013). There are also instances where the use of one scheme results in a high rating, yet the same building scoring much lower or failing a certification using another scheme (Roderick et al., 2009). Incongruities between ratings and end-user satisfactions have also been reported (Altomonte et al. 2017). In the light of these concerns, the chapter assesses the strengths and limitations of the transport category of Green Star South Africa rating system in terms of significance, comprehensiveness, relevance, accuracy and viability. This is important to help communicate what green star rating truly represent in the transport planning and management context. The assessment also reviews prospects of functionally improving the tool.

## Background

Within their computational frameworks, green building rating schemes incorporate building functional categories that include energy, transport, water, materials, waste, land use and ecology, health and wellbeing of users, pollution and innovation. Each category contains credits that can be earned through fulfilling specified criteria. Credits are usually a function of the extent to which measures are implemented to reduce energy consumption and greenhouse gas emissions.

The Green Star South Africa rating scheme, founded on the Australian Green Star, was introduced in 2008 by the Green Building Council South Africa (GBCSA), much later than BREEAM in 1990 and LEED in 1998. To aid its implementation, the Green Star SA software platform Office Version 1 was released, followed by Version 1.1 in 2014. In June 2017, GBCSA released a scoping paper for the Green Star SA-New Build Tool-Version 2. The New Build Tool platform is scheduled for launch in August 2018. In this new platform, four different rating tools (office, retail, residential and public/

education) will be combined into a single tool, in line with international trends (GBCSA, 2017b). However, the scoping paper makes no mention of modifications to the transport category of the rating system.

Whereas in 2017 over 200 buildings in South Africa had received certification, over 661 600 buildings around the world had been certified through BREEAM alone. Certification of green buildings in South Africa appears to be subdued by certification costs and the absence of government incentives (McGraw Hill Construction, 2013). Nonetheless, most of

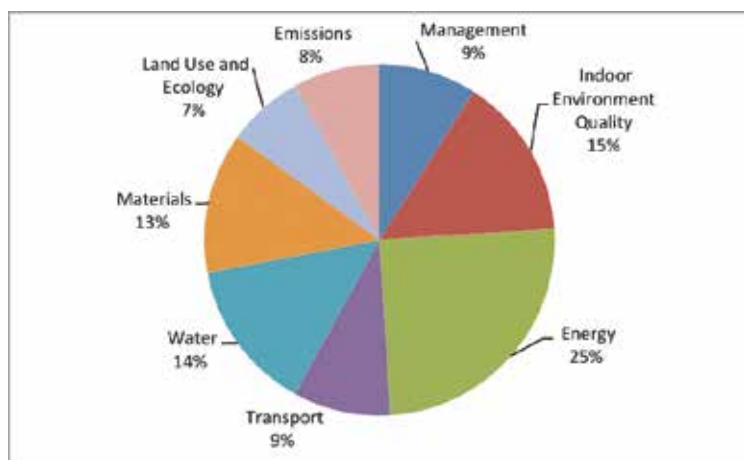


Figure 1: Sectoral weights in the Green Star South Africa tool

Table 1: Overall scores and ratings in the Green Star South Africa tool

Overall Score	Rating	Ratings outcome
10 - 19	One Star	Not eligible for formal certification
20 - 29	Two Star	Not eligible for formal certification
30 - 44	Three Star	Not eligible for formal certification
45 - 59	Four Star	Eligible for Four Star Certified Rating that recognises/rewards 'Best Practice'
60 - 74	Five Star	Eligible for Five Star Certified Rating that recognises/rewards 'South African Excellence'
75+	Six Star	Eligible for Six Star Certified Rating that recognises/rewards 'World Leadership'

South Africa's certified buildings are in Gauteng (56%), followed by the Western Cape (31%) and KwaZulu-Natal (9%). More than half of the certifications in Gauteng were for offices.

Considerations for green transport alternatives for use of buildings is a progressive new phenomenon in South Africa. Traditionally, the interface between buildings (land uses) and transport has mainly been limited to the use of various design guidelines, for example COTO (2012), to estimate minimum parking requirements and operational capacity of supporting transport infrastructure. For example, offices are expected to generate 8.5 vehicle trips per day (combined for both entry and exit) for every 100m<sup>2</sup> of Gross Leasable Area from which the required transport infrastructure is estimated. Nonetheless, such approaches are criticised for lack of micro-economic considerations (Shoup, 1999) and failure to advance the development of sustainable transport systems (Mingardo et al., 2015).

### **Overview of green star south africa's transport category**

The Green Star South Africa rating system has rating tools for purposes that include existing building performance, interiors, office, public and education, multi-unit residential, retail and sustainable precincts. Given that offices constitute most of the rating in Gauteng Province, the Office v1.1 tool was selected for further interrogation. Office v1.1 was released in 2014 and received only minor changes from the original 2008 version. The change log shows that the transport category has had no changes since 2008 (GBCSA, 2014).

Figure 1 shows the relative categorical weights used in Office v1.1 tool. Eight categories are used namely: management, indoor environmental quality, energy, transport, water, materials, land-use and ecology, emissions, and innovation. Transport has a relative weight of 9%. The scoring and overall rating system is summarised in Table 1. Buildings with overall

scores (credits) below 45 are not eligible for formal certification. A Four Star rating is considered "Best Practice", followed by Five Star rating ("South African Excellence") and Six Star rating ("World Leadership").

Transport has a maximum of 14 points derived from five credits, namely provision of car parking, fuel efficient transport, cyclist facilities, commuting mass transport, and extent of trip reduction through mixed use. The credits, together with their intended objectives and credit aim are summarised in Table 2. Provision of car parking (14%, which is the available points for this specific credit divided by the total points available for the transport category) rewards initiatives to minimise the need for parking. Fuel efficient transport (14%) rewards initiatives to encourage the use of more fuel efficient vehicles. Cyclist facilities (21%) is rated higher than the previous two, and rewards initiatives to facilitate the use of bicycles for the building. The commuting mass transport (36%) rewards the use of mass transport services to access the building. The points are awarded on the basis of the type of mass transport services available within 1km of the site, the number of routes serving the site, and public transport service headways during weekday peak periods. Finally, local connectivity (14%) rewards the location of building in mixed use areas.

Office v1-1 manual specifies criteria for the awarding of points for the different credits as follows:

Provision of car parking: Up to two points are awarded as follows: One point is awarded where the number of car parking spaces is: At least 25% lower than the maximum local planning allowances applicable to the project; or Not exceeding the minimum Department of Transport (DoT) guidelines by more than 10% or not exceeding the local planning minimum allowances by more than 10%, whichever is lower. Two points are awarded where the number of car parking spaces is: At least 50% lower than the maximum local

Credit Code	Credit name	Aim of credit	Points available	Percentage in transport category
Tra-1	Provision of car parking	Encourage and recognise developments that facilitate the use of alternative modes of transport for commuting to work	2	14
Tra-2	Fuel-efficient transport	Encourage and recognise developments that facilitate the use of more fuel efficient vehicles for commuting to work	2	14
Tra-3	Cyclist facilities	Encourage and recognise developments that facilitate the use of bicycles by occupants and customers	3	21
Tra-4	Commuting mass transport	Encourage and recognise developments that facilitate the use of mass transport for commuting to work	5	36
Tra-5	Local connectivity	Encourage and recognise developments that are built in mixed-use areas in order to reduce the number of trips and trip lengths	2	14
Credit Code	Credit Name	Aim of Credit	Points available	Percentage in transport category
		and trip lengths		
Total points			14	100

Table 2: Credits for the transport category

planning allowances applicable to the project; or not exceeding the minimum DoT guidelines or not exceeding the local planning minimum allowances, whichever is lower.

**Fuel efficient transport:** Two points are awarded where: A minimum of 5% of all parking spaces are dedicated solely for use by car-pool vehicles, car share vehicles, hybrid or other alternative fuel vehicles. All qualifying spaces must be located in preferred parking locations and be designed and labelled for the intended vehicle types; and a minimum of 5% or 5 parking spaces (whichever is the greater) are designed and labelled for mopeds, scooters and/or motorbikes, and all of these must be located in preferred parking locations.

**Cyclist facilities:** Up to three points are awarded as follows: One point is awarded where the following are provided: secure bicycle storage for 3% of building staff, accessible showers, changing facilities adjacent to showers, and one secure locker per bicycle space in the changing facilities. Two points are awarded where the following are provided: secure bicycle storage for 6% of building staff, accessible showers, changing facilities adjacent to showers; and one secure locker per bicycle space in the changing facilities. An additional point is awarded where: the requirements for either one or two points have been met; and visitor bicycle parking is provided and meets the following criteria: one space per 750m<sup>2</sup> usable area or part thereof; and provided in an accessible location, signposted and close to, or adjacent to, a major public entrance to the building.

**Commuting mass transport:** Up to five points are awarded for the quality of mass transport options available to building occupants. The points are determined using the Green Star South Africa Commuting Mass Transport Calculator based on the number of public transport services provided in each of these categories: (i) The type of mass transport services available within 1 km of the site, (ii) The

number of routes served; and (iii) the average interval between services during weekday peak hours. Trains get relatively more points than road based services, and contracted road based services get more points than non-contracted services.

**Local connectivity:** One point is awarded where: any four of the following are located within 400m of a public entrance to the building: Bank/ATM, convenience grocery/supermarket, day care, cleaners/laundry, medical/dental offices, pharmacy, post office, restaurant/canteen/cafeteria, fitness centre/gym, library, school. An additional one point is awarded where: there is a minimum average gross density of 35 du/ha (dwellings units per hectare) for the entire area within 400m of the office development.

It is clear from the above allocation of points that the allocation system is supply driven. This is because it is largely assumed that by implementing such interventions as reduced parking spaces, and locating the building near public transport routes, that the users of the building will respond accordingly.

In terms of publicity and end-user interactions, GBCSA initiated stakeholder engagements about the major version change to a Green Star South Africa New Build Tool (GBCSA, 2017a; GBCSA, 2017b). The associated report was published in April 2017. Furthermore, GBCSA conducted online surveys, telephonic interviews, focus groups, external scoping workshops and also requested consultants to do a credit-by-credit review of the rating system.

In terms of the review, majority of consultants felt that only minor or no changes to the commuting mass transport credit needed to be made. They also felt that a benchmark update is not needed and that this credit should not be removed. They also felt that there is a low level of cost associated with this credit. One company remarked that the

credit does not inspire change, while another commented that submission documentation is complicated.

Table 3 provides a summary assessment of how transport is treated in other rating schemes (BREEAM, LEED, and Australia's Green Star). While not completely comparable, key differences between South Africa's Commuting Mass Transport calculator and other tools are in terms of: transport's relative weight in the system, size of the credit points, linkages with transport authority transport planning tools, and the definition of public transport access.

### **Situational analysis of buildings already rated in gauteng province**

Figure 2 shows the location of buildings that have already been green certified in Gauteng Province. The buildings tend to be clustered and located near arterial roads. Out of all the rated buildings, five were selected, ranging from Four to Six Star rating, for further situational analysis. For these five buildings, Table 3 provides some of the transport-related indicators derived from the 2014 Gauteng household travel survey (GDRT, 2014), that are associated with areas (transport zones in the Gauteng Province's Strategic Transport Model) in which the buildings are located.

All the relevant areas selected (transport zones) have sizable numbers of incoming and outgoing person trips in the morning peak period (06h00 to 09:00). With regard to mode split i.e. train, bus, minibus taxi (taxi), non-motorised transport (NMT), private car, and other; the predominant mode of transport for trips to/from areas in which these building are located is private cars. Besides minibus taxis, public transport makes a very small proportion of trips in these areas, even for a building with a Six Star rating ("World Leadership"). In fact, a further analysis of proximity of all the rated buildings in Gauteng Province, to public transport services, shows that 37%, 89%, and

100% of these buildings are within 1km of rail lines, bus routes, and minibus taxi routes, respectively.

Nedbank Lake View building, with a Four Star rating, is located within an area with a relatively large proportion of non-motorised trips. Despite this, the building only scored less than 50% of the points in the transport category for this development. The observed disconnect between transport and the building performances is because mode split is influenced by many other built environment attributes such as density, urban form, and accessibility in relation to traveller attributes (Holtzclaw, 1994; Ewing & Cervero, 2001; Murray, et al., 1998; Dargay & Hanly, 2003), which is not explicitly taken into account in the tool's evaluation framework. Similarly, increased parking cost is most effective for reducing parking demand (Christiansen, et al., 2017), and the availability of free parking results in travel behaviour that is inelastic to such things as mode choice incentives (Hamre and Buehler, 2014). Restricting parking on the other hand could have unintended consequences of overspill to the surrounding areas (Melia & Clark, 2017). With regard to cycling, the absence of good cycling infrastructure in the functional area of the property greatly reduces attractiveness of cycling trips (Hunt & Abraham, 2007; Larsen & El-Geneidy, 2011). Many of these micro-economic considerations, however, are not taken explicitly into account within the tool's evaluation framework.

For the selected buildings, average trip lengths, most of them by private car, range from 30 to 42 minutes. A Six Star rated building is located in an area with an average trip length of 38 minutes. Public transport access times for trips originating or destined in these areas are particularly long for train users and much shorter for minibus taxi users. Under these circumstances, locating a building near public transport routes, without considering



Tool	Notable features
<p>BREEAM</p> <p>(BRE, 2016; TfL, n.d.; TfL, 2015)</p>	<ul style="list-style-type: none"> <li>• Transport has a weight of 6.77% of available credits</li> <li>• There are 13 credits available in the transport category and up to 5 credits are available for public transport accessibility</li> <li>• Unlike Green Star SA, frequency of service is defined as the average number of services stopping per hour at each node during the operating hours of the building per day and not during peak periods.</li> <li>• For buildings in the Greater London area, BREEAM allows for the use of Transport for London's WebCAT (Web-based connectivity assessment toolkit) to find an area's Public Transport Accessibility Level (PTAL) which can be used as evidence for Accessibility Index points.</li> </ul>
<p>LEED</p> <p>(USGBC, n.d.; USGBC, 2014)</p>	<ul style="list-style-type: none"> <li>• Public transport access is classified under the location and transportation category.</li> <li>• Access to Quality Public Transport has up to five credits.</li> <li>• If any bus, streetcar or informal public transport stop is within ¼ mile (400m) walking distance of the building or any bus rapid transit stop, rail station or ferry terminal is within a ½ mile (800m) walking distance, then the public transport services at those stations and stops must meet some minimum requirements for both weekday and weekend trips.</li> <li>• Projects served by one or more public transport routes such that no one route provides more than 60% of the prescribed levels may earn one additional points, up to the maximum number of points.</li> </ul>
<p>Green Star (Australia)</p> <p>(GBCA, 2015)</p>	<ul style="list-style-type: none"> <li>• Green Star has developed a unique Public Transport Accessibility Index (PTAI) to determine a project's accessibility. Instead of using the BREEAM's PTAL methodology it uses overall accessibility modelling.</li> <li>• Green Star measures accessibility as the number of project occupants that can access the nominated destination through the use of public transport within a 45 minute travel time threshold. This 45 minute threshold is a door-to-door travel time that includes walk time to and from the public transport stop at both ends of the trip, in-vehicle time, wait/transfer time and "dead" time (the difference between the desired arrival time and the actual arrival time (GBCA, 2015).</li> <li>• Up to three points are available for the 'Access by Public Transport' credit. The points are awarded in accordance to the proportion of city residents that can access the nominated area in 45 minutes using public transport compared to the total population of the city's total population.</li> </ul>

Table 3: Summary assessment of the notable features of how transport is treated in other schemes

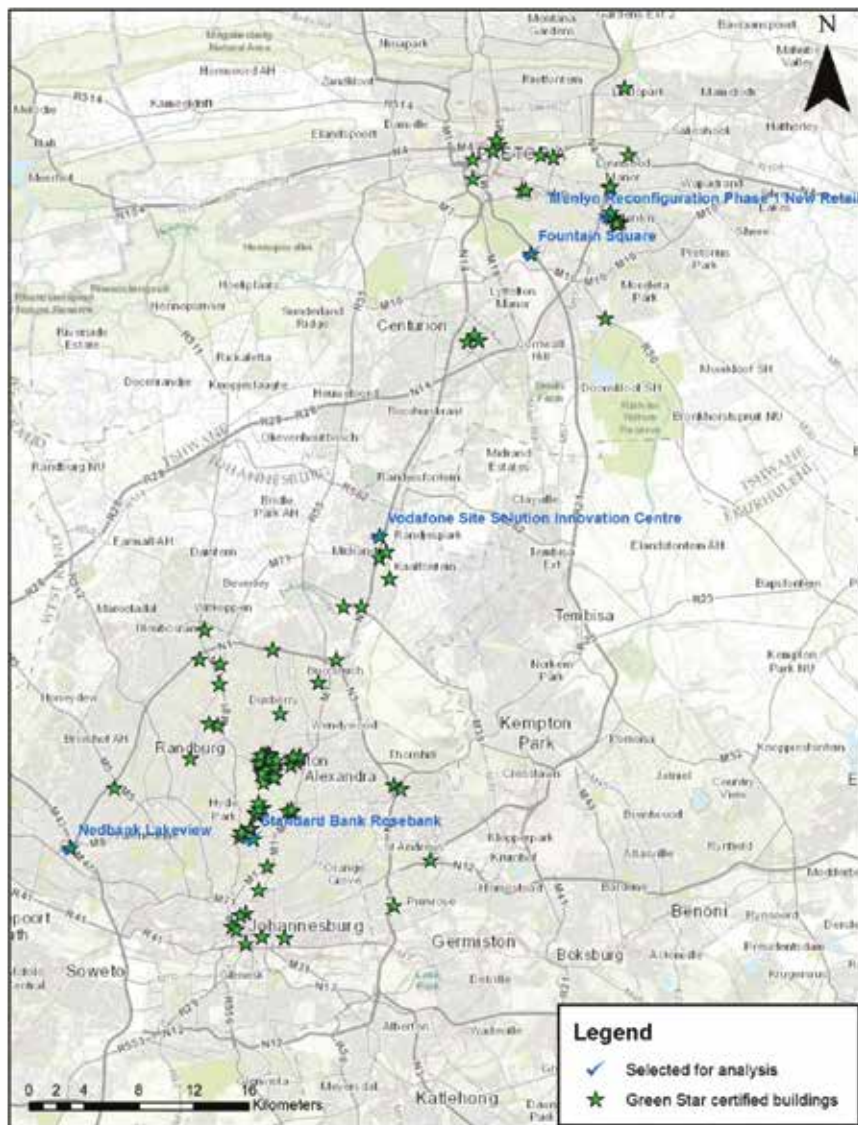


Figure 2: Location of green certified buildings in Gauteng Province

Name of certified building	Vodafone Site solution Innovation Centre	Nedbank Lakeview	Standard bank Rosebank	Menlyn Reconfiguration Phase1	Fountain square	
Green star type	Office	Office	Office	Retail Centre	Existing Building performance	
Green Star South Africa Rating	6	4	5	4	4	
Reported transport category points achieved (As % transport category points)	<50%	<50%	50%-60%	90%-100%	90%-100%	
Modal split (%)	Train	1	3	1	0.20	0.10
	Bus	3	8	2	2	2.7
	Taxi	13	19	5	2.50	3.4
	NMT	6	35	10	6	12
	Private	74	35	82	87	81
	Other	3	0	0	2	1
Average trip length for all trip purpose (min)	38	44	30	38	42	
Total person trips (06h00 - 09h00)	Origin	29 077	69 611	24 543	15 993	51 955
	Destination	38 013	96 563	77 826	40 893	47 544
Mean household Access times to public transport services (min)	Train	38	20	20	27	32
	Bus	15	11	10	8	8
	Taxi	8	8	9	10	10

Table 3: Transport related data for selected green certified buildings in Gauteng

the quality of the service, which users would ordinarily do, limits the efficacy of the tool's evaluation framework.

What is clear in this situational analysis is that, from a transport perspective, building performance ratings in the Green Star South Africa tool, have little to do with the functional relationship between the users of the building and the operations of transport within the functional area of the building. Buildings are essentially rated in isolation of surrounding transport conditions. It is unlikely therefore

that a high rating using the current tool would be indicative of desirable transport conditions within the functional areas of the building.

### **Consolidated evaluation of green star south africa's transport category**

The Green Star South Africa transport category has the stated objective of rewarding the reduction of automotive commuting by simultaneously discouraging it and encouraging use of alternative transport. While

this is acknowledged, Table 4 summarises some of the tool's observable strengths and limitations (including its co-benefits) for each credit based on the observations made on some of the buildings that have already been certified and transport literature.

Many of the tool's weaknesses in Table 4 relate to its disregard for transport performance in a network context as indicated in the previous section. In contrast, Australia's Green Star rating tool comes close to taking the network context into account in that it measures accessibility as the number of building users who can access the building/area by public transport within a 45 minute travel time threshold (which South African buildings are not likely to pass). Such levels of accessibility would be truly indicative building accessibility by public transport. Moreover, in a network context, individual travellers make decisions about where to travel, which mode of transport to use, what time to travel, which route to use, and which destination to travel to by evaluating all known options in the network. In the manner built (supply oriented and insensitive to travel behaviour in a transport network), the South African tool cannot therefore be used to make inferences about the sustainability of rated buildings from a transport perspective.

Future updates of the tool should consider incorporating network effects in order to improve its effectiveness, for example using network transport models to estimate the nature of travel demand in which buildings are located. The application of simplified modelling approaches, yet behaviourally rich, for the South African contexts suggested by Venter and Mokonyama (2009), should be explored. The retrospective use of actual travel behaviour as opposed to assumed travel behaviour from the supply of "green" transport infrastructure would also serve to truly evaluate the building performance from a transport perspective. Improved incorporation of traveller characteristics would also render the tool more useful, especially with regard to minimising unintended social exclusion.

## Conclusions

The chapter reviewed the strengths and limitations of the Green Star South Africa rating scheme in respect of its transport environment category. The transport category has the stated objective of rewarding the reduction of automotive commuting within the built environment by concurrently discouraging it and encouraging use of alternative transport. The credits and associated points of the transport category were reviewed in detail, and comparisons with similar tools used elsewhere in the world were drawn. The chapter also provided a situational review of selected green certified buildings in Gauteng Province.

It is concluded from the review of the transport category of Green Star South Africa's rating scheme that the tool requires significant improvements in order to truly be reflective of sustainable transport ideals. This is because the tool is currently configured for isolated assessments of buildings as opposed to evaluating such buildings in the required transport network context. Results from the ratings are therefore more reflective of assumed probable behavioural outcomes from the supply of "green" transport infrastructure elements as opposed to the actual functioning of buildings to reduce transport-related energy use and emissions. Despite the onerous requirements in the form of support documents to implement the transport tool, as expressed by some industry representatives that submission documentation is complicated, the outcomes of the ratings produce limited returns for transport planning purposes.

The review of similar tools from other parts of the world shows that collaboration between developers and authorities may be essential to improve its efficacy, for example, using the authority's network transport models and associated datasets. The retrospective use of actual travel behaviour as opposed to assumed travel behaviour from the supply of "green" transport infrastructure would serve

Rating dimension	Strengths	Limitations
Provision of car parking	<ul style="list-style-type: none"> <li>▪ Possibility of realising reduced number of vehicle trips per building.</li> <li>▪ Physical reduction of expensive urban space devoted to the use private cars.</li> <li>▪ Developers are able to increase the size of lettable area.</li> <li>▪ Reduced overhead cost for tenants from reduced parking space costs.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Implemented in isolation there may be diversion of trips to other areas of the network without parking restrictions. This in turn may result in increased vehicle kilometres in the network, and in turn increase greenhouse gas emissions.</li> <li>▪ Possible increased number of illegal parking on-site if there are no alternative travel modes.</li> <li>▪ Exclusion of user charges for parking spaces limits behavioural responses.</li> </ul>
Fuel efficient transport	<ul style="list-style-type: none"> <li>▪ Reduction of vehicle kilometres per trip to or from the building.</li> <li>▪ Incentive for more building users to consider hybrid/alternative fuel vehicles.</li> <li>▪ Incentive for building users who already practice ridesharing or have hybrid/alternative fuel vehicles.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Increased use of mopeds, scooters and/or motorbikes which actually pollute relatively more than cars.</li> <li>▪ Exclusion of an average vehicle owner at the expense of higher income individuals given the relatively high prices of alternative fuel vehicles.</li> </ul>
Cyclist facilities	<ul style="list-style-type: none"> <li>▪ Incentive for building users who already use bicycles.</li> <li>▪ Incentive for more building users to consider using bicycles.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Trip lengths in South Africa are typically long and not conducive for cycling.</li> <li>▪ In the absence of an appropriate cycling network in the functional areas of the building, cyclists will have high risk exposure.</li> </ul>
Commuting mass transport	<ul style="list-style-type: none"> <li>▪ Incentivises developments in the vicinity of high capacity public transport services.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Public transport services in the vicinity of the building, that are used to rate the building, may not be functionally linked to the building itself.</li> <li>▪ Places burden on developers who have little control on the development and management of a</li> </ul>

		<p>control on the development and management of a public transport networks.</p> <ul style="list-style-type: none"> <li>▪ While minibus taxis are prevalent, emphasis is placed on contracted services.</li> <li>▪ Incentivises resource constrained peak travel on public transport and disregards the need to incentivise improved use of off-peak services. Low occupancy off-peak services pollute relatively more per vehicle kilometre.</li> </ul>
Local connectivity	<ul style="list-style-type: none"> <li>▪ Potential to reduce number of motorised trips per building user.</li> <li>▪ Potential to increase the proportion of non-motorised trips.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Assumes functional linkages between the building and surrounding land uses. Such functional linkages are likely to be limited if implementation is in isolation of a wider spatial development strategy and result increased network congestion in the vicinity of the building.</li> </ul>

Table 4: Strengths and limitations of South Africa's transport environmental category

to truly evaluate the building performance from a transport perspective.

### Recommendations

Fundamental updates of the Green Star South Africa rating scheme in respect of its transport environment category are warranted. However, this should be a collaborative initiative between the Green Building Council of South Africa and transport planning authorities in the country. In this

regard, transport planning authorities should produce up to date transport network data and tools for use by developers in applying the rating tools. A basic green transport map of a city should in fact be the responsibility of transport planning authorities. Given voluntary nature of the rating schemes, such collaboration is likely to incentivise more developers to use the rating tools.

## References

- BRE, 2016. BREEAM International New Construction 2016: Technical Manual, Watford, Hertfordshire: Building Research Establishment.
- Castillo, H. and Pitfield, D.E. 2010. ELASTIC – A methodological framework for identifying and selecting sustainable transport indicators. *Transportation Research Part D*, 15, 179–188.
- Christiansen, P., Engebretsen, Ø., Fearnley, N. & Hanssen, J. U., 2017. Parking facilities and the built environment: Impacts on travel behaviour. *Transportation Research Part A*, Issue 95, pp. 198–206.
- Dargay, J. M. & Hanly, M., 2003. The Impact of Land Use Patterns on Travel Behaviour. Strasbourg, European Transport Conference.
- Doan, D. T. et al., 2017. A critical comparison of green building rating systems. *Building and Environment*, Volume 123, pp. 243-260.
- Ewing, R. & Cervero, R., 2001. Travel and the built environment: a synthesis. *Transportation Research Record*, 1780, pp. 87-114.
- GBCA, 2015. Access by public transport calculator guide, Sydney: Green Building Council of Australia.
- GBCA, n.d. The what and why of certification. [Online] Available at: <http://new.gbca.org.au/green-star/> [Accessed 14 August 2017].
- GBSCSA, 2014. Technical Manual- GSSA Office v1.1, Johannesburg, South Africa.
- GBSCSA, 2017a. Green Star SA New Build Tool - version 2: Stakeholder Engagement Report, Cape Town: Green Building Council South Africa.
- GBSCSA, 2017b. Green Star SA New Build Tool-Version 2, Scoping Paper, Observatory: Green Building Council South Africa.
- GDRT, 2014. Gauteng Province Household Travel Survey, Johannesburg: Gauteng Province department of Road and Transport.
- Holtzclaw, J., 1994. Residential Patterns and Transit, Auto Dependence, and Costs, San Francisco. : Resources Defense Council.
- Hunt, J. D. & Abraham, J. E., 2007. Influences on bicycle use. *Transportation*, Volume 34, pp. 453-470.
- Illankoon, I., Tam, V., Le, K. & Shen, L., 2017. Key credit criteria among international green building rating tools. *Journal of Cleaner Production*, Volume 10.1016/j.jclepro.2017.06.206, pp. 209-220.
- Larsen, J. & El-Geneidy, A., 2011. A travel behavior analysis of urban cycling facilities in Montréal, Canada. *Transportation Research Part D: Transport and Environment*, 16(2), pp. 172-177.
- Mao, X., Lu, H. & Li, Q., 2009. A comparison study of mainstream sustainable/green building tools in the world, Wuhan, China: International Conference on Management and Service Science.
- McGraw Hill Construction, 2013. World Green Building Trends: Business benefits driving new and retrofits market opportunities in over 60 countries, New York: McGraw Hill Construction.
- Melia, S. & Clark, B., 2017. What happens to travel behaviour? Dublin, Ireland, Universities Transport Study Group Conference.
- Mingardo, G., Van Wee, B. and Rye, T. 2015. Urban parking policy in Europe: A conceptualization of past and possible future trends. *Transportation Research Part A*, 74, 268–281.
- Murray, A., Davis, R., Stimson, R. & Ferreira, L., 1998. Public transport access. *Transportation*

- research D, Volume 3, pp. 319-328.
- NDoT, 1996. White Paper on National Transport Policy, Pretoria: National Department of Transport.
  - SEA, 2015. State of Energy in South African Cities, Published by Sustainable Energy Africa, Cape Town.
  - Shoup, D.C. 1999. The trouble with minimum parking requirements, Transportation Research Part A, 33, 549-574
  - TfL, 2013. London datastore. [Online] Available at: <https://data.london.gov.uk/dataset/public-transport-accessibility-levels> [Accessed August 2017].
  - TfL, 2015. Assessing transport connectivity in London. [Online] Available at: <http://content.tfl.gov.uk/connectivity-assessment-guide.pdf> [Accessed 12 October 2017].
  - TfL, n.d. Planning with WebCAT. [Online] Available at: <https://tfl.gov.uk/info-for/urban-planning-and-construction/planning-with-webcat> [Accessed 11 August 2017].
  - TfL, n.d. WebCAT. [Online] Available at: <https://tfl.gov.uk/info-for/urban-planning-and-construction/planning-with-webcat/webcat?intcmp=25932> [Accessed 12 August 2017].
  - USGBC, 2014. LEED v4: User Guide, Washington, D.C: United States Green Building Council.
  - USGBC, n.d. LEED BD+C: New Construction: LEED v4. [Online] Available at: <https://www.usgbc.org/node/2615193?return=/credits/retail---new-construction/v4> [Accessed 11 August 2017].
  - Venter, C. and Mokonyama, M. 2009. UPTRANS: An incremental transport model with feedback for quick-response strategy evaluation. Proceedings of the 28th Southern African Transport Conference, Pretoria, South Africa.



# Chapter 7

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## Literature review on skills development frameworks for small and medium-sized contractors in the green building sector

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## Introduction

In 2011 the Department of Public Works adopted a Green Building National Framework aimed at creating a collaborative enabling environment for construction and operation of sustainable environment activities by the public and private sectors in South Africa (Department of Public Works, 2011). The green building sector in South Africa is growing exponentially, as indicated by increased certification of 180 green buildings between 2007 and 2016 (Green Building Council of South Africa (GBCSA), et al, 2016).

The transformation and mainstreaming of the green building sector in South Africa is reliant upon massive development of green building-related skills. The general shortage of critical skills as well as poor quality of existing skills in South Africa, and in the construction and building sector in particular, is well documented (construction industry development board (cidb), 2003; Kraak, 2005; cidb, 2007; McGrath and Akoojee 2007). Too often the skills-related problems in building projects are blamed for poor performance as manifested through shoddy workmanship, too many injuries and fatalities due to accidents and cost and time overruns.

The green building sector is markedly different from the traditional building sector. Green building means “applying the principles of sustainable development to a comprehensive construction cycle from the extraction and beneficiation of raw material, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste” (International Research Council for Building and Construction (CIB), 2002). While design and construction/building processes are familiar processes in the traditional building economy, manufacturing processes are not well understood. Manufacturing plays an increasingly important role in the green building sector. Green building is a holistic process aiming to restore and maintain

harmony between the natural and built environments while creating settlements that affirm human dignity and encourage economic equity (Department of Public Works, 2011).

A clear distinction should also be made between entrepreneurial activities and general business management to avoid confusion and over-generalisation when dealing with these two concepts. While the former is concerned with early development and start-up activities of the firm, the latter deals with the aspects of managing an established firm (Urban, 2008). Skills development frameworks explored in this chapter should thus be navigated carefully, taking into consideration these overlapping aspects of small business development.

This chapter is an exploratory study based on literature review. The aim is to identify current skills development frameworks in the building sector and also presents an analysis of their characteristics. Thematic analysis was used to analyse a number of articles in order to develop an appropriate framework for supporting future skills development programmes and tools for the green building sector.

## Defining a green contractor

Generally speaking a green enterprise is one that embraces the core principles of sustainable development in all aspects of its operations, products and services. The sustainability principles entail managing an enterprise in a manner that takes care of social and economic progress while maintaining the environmental balance. The desire for such an enterprise to ‘do good and no harm’ is as strong as its profit motive and equally important in terms of the goals of the business (International Labour Organisation (International Labour Organisation (ILO), 2013a).

A green construction contractor thus takes great care in ensuring that it uses green materials to construct buildings. Green materials are typically produced from renewable resources, processed using low energy, and have low or no volatile organic compounds

(VOCs). A green contractor cares for the well-being of its employees in terms of health and safe working methods and fair remuneration processes – promoting the so-called smart jobs or descent work. The use of skilled local labour is maximised as far as possible and gender equality is strongly promoted within an enterprise. A green contractor therefore adopts principles, policies and practices that improve the quality of life for their customers, employees and the communities in which they operate (International Labour Organisation (ILO), 2013a).

### **Literature on entrepreneurship and skills development frameworks**

Entrepreneurship has a long history dating as far back as the fourteenth century. The term 'entrepreneur' was defined by Cantillon in the seventeenth century (Schumpeter, 1954). Nowadays the teaching of business and entrepreneurship skills is a common practice in many institutions of education, including in many schools; and this development has helped greatly to debunk the myth that 'entrepreneurs are born, not made'.

The problem of shortage of critical skills as well as poor quality of existing skills in South Africa, and in the construction and building sector particularly, is well documented (construction industry development board (cidb), 2004; Kraak, 2005; cidb, 2007; McGrath and Akoojee 2007). A cursory observation into the National Scarce Skills List (Department of Labour, 2010) shows that building and manufacturing skills account for 60% of the total skills shortage in South Africa which is estimated at 42,850. The research on construction industry skills by the construction industry development board (cidb) (2011) concluded that less than 5% of lower level owner contractors (Grade 2-4) have a management qualification. Around 30% of employees in this category do not have a technical qualification.

In building projects, poor business management and poor project management are blamed for

a number of performance-related problems (cidb, 2009), with the main culprits being:

- Poor quality of workmanship which compromises structural integrity of buildings and safety of the occupants;
- Time and budget overruns resulting in late completion of projects and delayed occupancy of buildings;
- Budget overruns resulting in reduced impact and compromised service delivery;
- Time overruns resulting in late completion of projects and delayed occupation of buildings; and
- Budget overruns resulting in reduced profitability and compromised service delivery.

The analysis of countries' experiences reveals that skill shortages constrain the transition to a green economy – in terms of filling the posts for new occupations and in terms of changing the skill profile of a large number of occupations (International Labour Organisation (ILO), 2011). The research also documents the need to provide opportunities for acquiring new skills to those who are at risk of losing jobs in the high-emissions industries (International Labour Organisation (ILO), 2011). The adoption of training frameworks varies according to different countries. Some countries develop training strategies and policies to proactively anticipate and meet the challenges of new skills, whereas other countries adjust existing mechanisms and systems on an ad hoc basis (International Labour Organisation (ILO), 2011).

The availability of workers and enterprises with appropriate green skills is critical role for green transformation. Employers investing in the green technologies need to be able to find workers with the right skills (International Labour Organisation (ILO), 2011). Workers and communities that lose jobs in the 'brown' industries need opportunities to develop new skills for the green economy (International Labour Organisation (ILO), 2011).

The challenges relating to entrepreneurship and business skills internationally and in the South African construction sector have resulted in the development of a number of interventions and frameworks aimed to address these challenges.

### **Critical success factors for small enterprises**

A number of critical success factors (CSFs) for small construction enterprises have been identified by many researchers across a number of countries (e.g. Moss et al, 2008; Dlungwana, 2011; Lu & Shen, 2008). In the effort to ensure the impact of skills development programmes, it is worthwhile assessing these programmes against these key success factors.

Based on the small contractor development programmes conducted in South Africa's Eastern Cape province, Dlungwana (2011) identifies the CSFs for contractors in the programme as tendering skills, project costing and project management. All these were grouped under the broad theme of business management skills.

In a study across three large provinces in China, Lu et al (2008) identified 48 critical success factors (CSFs) for Chinese contractors. The top ten of these CSFs were: Bidding strategy; An explicit competitive strategy; Relationship with government departments; Cost management; Sustainable development of human resources; Communication and coordination among functional departments; Risk management; Quality management; Strategic awareness and perspective and Site management. The findings of this research corroborated with research in many other countries although there were also notable differences, particularly in the order of importance of the CSFs.

Studies conducted in the UK show that good corporate governance practices on environmental and social issues enhances companies' shareholders value, or at the very least, protects their highly valuable reputations (Sustainable Construction Task Group (SCTG),

2002). A study showed that those companies with the respect for the environment (FTSE4Good companies) are considered to have performance than conventional FTSE100 companies. A similar study showed that on the Dow Jones index environment-friendly companies outperformed their other peers by 15% (Sustainable Construction Task Group (SCTG), 2002). Tan et al recognise the linkage between sustainability performance and business competitiveness (Tan et al, 2011). These studies demonstrate that implementation of sustainable construction practices can be a critical success factor because the positive messages created about a contractor may lead to competitiveness in the marketplace.

The World Bank identifies five key support areas for green SMEs that governments, developing agents and other actors in developing countries should promote (International Bank for Reconstruction and Development, 2014). These areas are entrepreneurship and business acceleration, innovation and finance, market development, technology development, and legal and regulatory framework.

The above CSFs are not exhaustive but provide an indication of some important aspects that should be used as benchmarks in assessing the impact of skills development.

### **Different approaches to skills development frameworks**

Gibb's approach to entrepreneurship teaching entails 'generative learning', i.e. learning that embodies capacity to create and bring forward experience, rather than waiting for (and learning from) it (Gibb, 1997). Gibb argues that positivist-type approaches to small enterprise learning are inadequate as they do not harness understanding of the process of learning and he asserts that there is a best chance of successful learning if there is a thorough understanding of the process. Gibb also advocates for the learning process that involves, not only the

business owner, but also the associated stakeholders, including client, suppliers and financiers – the so-called 'learning circle' (Gibb, 1997).

A national study conducted by the CIDB revealed that in 2009 there were 18 contractor development programmes (CDPs) involving some 1300 contractors (construction industry development board (cidb), 2009). Existing programmes vary from one another to a lesser or greater extent, and are typically characterised by the following features:

- **Procurement-driven support measures:** Most of the skills development programmes in South Africa are driven by public sector clients (e.g. government departments, municipalities and state-owned enterprises) through the procurement process. The key objective of a number of demand side measures is to create an enabling environment that supports small and medium size enterprises. The support measures may include quicker payment schedules, simplified bidding documents and relaxation of bonds and guarantees.
- **Theoretical training:** A number of skills development programmes include theoretical training as a strong component of the programme. The objective of such training is to provide a good grounding of the construction and building theory from entrepreneurial, managerial and technical perspectives.
- **Work (practical) Training:** The theoretical training is backed by a practical on-the-project experience where the entrepreneur and the organisation's senior staff are mentored by an experienced mentor. Mentorship is a point where theory and practice come together to create true learning, knowledge and lasting skills.
- **Monitoring and evaluation:** The cidb guidelines (construction industry development board (cidb), 2009) for skills development put emphasis on the need to monitor and evaluate the skills development frameworks in order to ensure high quality of training and mentorship. The monitoring and evaluation process thus facilitates assessment of the quality of skills being acquired by the entrepreneur, top management, and staff and provides a feedback mechanism for improving the training programmes.
- **Minimum risk for contractors:** It is important for the enterprise to risk something into the programme in order to solicit their commitment. Most programmes are criticised for absorbing full costs of the programmes resulting in enterprises failing to appreciate the importance of such opportunities as they contribute nothing for their development. Too often the skills development programmes have been criticised as job creation schemes that perpetuate entitlement to work dependency rather than creating sustainable skills desperately needed by the sector.

### **Frameworks for skills development in the construction and building sector**

Since 1994 the construction and building sector has elevated skills developed by implementing numerous skills development frameworks targeted at improving the capacity of both the entrepreneurs and workers. Training of professionals, such as architects and engineers, adopts a different framework for skills development, which ranges from degree and diploma studies at educational institutions. There are also continuing professional development (CPD) courses offered to supplement their

Table 1 summarises the types of categories of skills development frameworks identified within the South African building sector.

Framework category / type	Description	Key features	Key stakeholders	Comment
A) Procurement driven enterprise development programmes	A group of suppliers/contractors are trained within a skills training programme thorough theoretical and practical training	<ul style="list-style-type: none"> <li>• Entrepreneurial skills</li> <li>• Business management skills</li> <li>• Training</li> <li>• Mentorship</li> <li>• Formalised monitoring</li> <li>• Formalised evaluation</li> </ul>	<ul style="list-style-type: none"> <li>• Small/medium enterprise</li> <li>• Public sector government departments,</li> <li>• Municipalities</li> <li>• SOEs</li> <li>• CETA</li> </ul>	Examples of programme: EPWP's Vuk'uphile Learnership Programme driven by the Department of Public Works; or Eskom Construction Academy
B) Procurement-driven employee skills development programmes	A group of employees are selected into a skills training programme thorough theoretical and practical training	<ul style="list-style-type: none"> <li>• Trade skills</li> <li>• Training</li> <li>• Mentorship</li> </ul>	<ul style="list-style-type: none"> <li>• Employees</li> <li>• Public sector government departments,</li> <li>• Municipalities</li> <li>• SOEs</li> <li>• Universities</li> <li>• Colleges</li> <li>• CETA</li> </ul>	Examples: Certificate in Occupational Health & Safety; Certificate in Bricklaying; Certificate in Plumbing
C) University / college training programmes	High level academic training of students for a year and above. Programme lead to professional registration	<ul style="list-style-type: none"> <li>• Theory-intensive courses</li> <li>• Practical experience for some qualifications</li> <li>• Little or no practical training for other qualifications</li> </ul>	<ul style="list-style-type: none"> <li>• Student</li> <li>• Universities</li> <li>• Colleges</li> </ul>	Examples: Degree/ Diploma in Quantity Surveying, or Construction Management, or Architectural Studies
D) Skills transfer from large, established enterprises to small, emerging enterprises	Main contractor and sub-contractor work together with the intention of transferring critical skills to those with capacity problems	<ul style="list-style-type: none"> <li>• Project-based mentorship</li> </ul>	<ul style="list-style-type: none"> <li>• Large, established enterprise</li> <li>• Small/medium enterprise</li> </ul>	Example: KwaZulu Natal's eThekweni Large Contractor Model
E) Programmes and courses designed to provide information or awareness on green building	The programme introduces small entrepreneurs into the green building sector and provides skills through a series of training modules	<ul style="list-style-type: none"> <li>• Entrepreneurs in construction sector</li> <li>• ILO-accredited trainers</li> </ul>	<ul style="list-style-type: none"> <li>• Small/ medium enterprise</li> <li>• International Labour Organisation (ILO)</li> </ul>	Example: Start and Improve Your Green Construction Business (SIYGCB)

career development on a long-term basis. The summary of literature covered here focuses on skills development frameworks designed for small and medium sized contractors at both entrepreneurial/managerial level and employee level. In small contractors there is, however, a thin line between the entrepreneurial/managerial tasks and technical tasks since the entrepreneur and top management staff tends to get involved at many levels of the business operations. This means that skills development interventions should embrace a holistic, cross-cutting approach for the small enterprise.

Despite a number of contractor development programmes implemented in the construction sector in South Africa, Qongqo et al (Qongqo & Mphahlele, 2014) note that the impact of CDPs in terms of growth of contractors (as measured by upgrading to higher grades) is not significant. To improve this situation they recommend that the National Contractor Development Programmes (NCDP) Guidelines be fully adopted by CDPs (Qongqo & Mphahlele, 2014; NCDP, 2011). With improved compliance to the NCDP Guidelines it is foreseen that a significant potential exists for CDPs in the future (Qongqo & Mphahlele, 2014).

### **Skills development frameworks in the green building sector**

The construction and building sector in South Africa is recognised as one where a high level of green economy awareness has been created (International Labour Organisation (ILO), 2010). The sector has a potential to spread green practices over a broad area of the sector as opposed to just influencing limited individual projects. Thus, knowledge pertaining to green building in this sector is seen to be growing (International Labour Organisation (ILO), 2010).

Category E in Table 1 describes arguably the only training programme relevant to green building skills framework among many conventional frameworks. The content of 'Start and Improve Your Green Construction Business (SIYGCB)' training programme is tailored specifically to address green/ sustainability issues that should be tackled by small construction contractors (International Labour Organisation (ILO), 2013b).

The objectives of the SIYGCB programme are to:

- enable local training providers to effectively and independently implement business start-ups and improvement training and related activities;
- enable potential and existing small businesses, both women and men, through the programme to start viable businesses and to create employment for others in the process;
- respond to business challenges in the construction and building environment with a view to environmental sustainability and green building best practice.

The paucity of skills development frameworks for green contractors in South Africa remains a concern that should be addressed in order to transit towards a thriving green building sector.

Green building projects have profound unique features when compared to conventional construction projects and these differences have implications for the skills development frameworks. In the main these differences relate to a contractual relationship between the Certificate Holder of the building system and the Licensee. The addition of the Agrément certificate into construction processes means the

Certificate Holder will be involved in both the design and construction stages of the project. The implications of such additional role player in contractual arrangements need to be carefully considered. If the Certificate Holder is appointed as the main contractor the relationships are similar to those of conventional contract arrangement with the difference being that the Certificate Holder will now be responsible for aspects of the design. However, if the Licensee is appointed as a contractor then the contractual relationships will be such that the Contractor has a contract with the client, but the Certificate Holder is not absolved from liabilities attached to the certificate, such as system performance

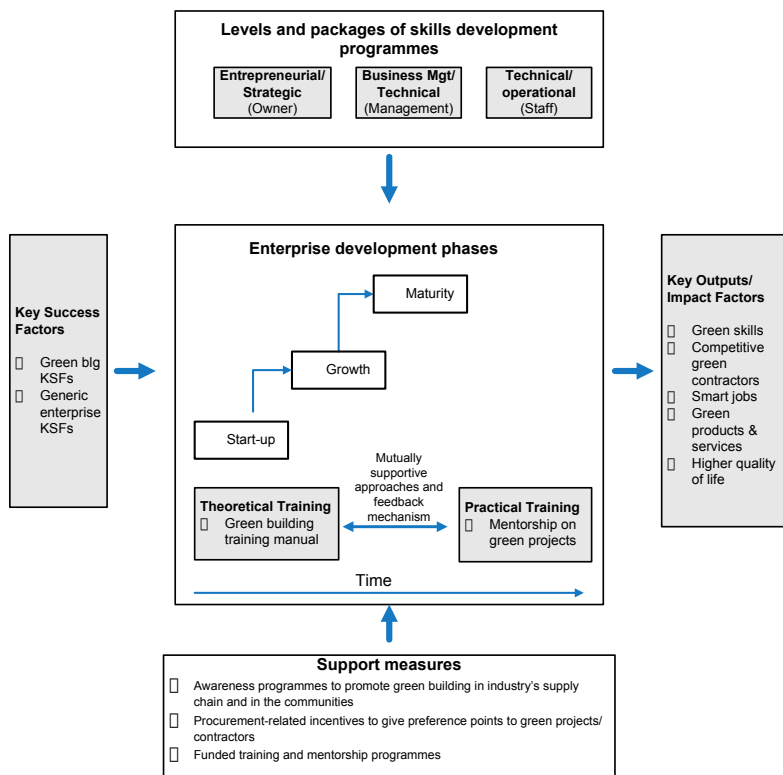
and quality assurance aspects. The training programme needs to clarify these relationships carefully among the role-players.

### Proposed framework for skills development in green building

#### Development priority on key success factors

The starting point of the proposed skills development framework for small green contractors is to understand the key success factors that should be mastered by a green contractor. Given the survivalist environment in which small contractors play, it is critical for the framework to prioritise marketing

Figure 1: Proposed skills development framework





skills that will make them attractive to clients and partners in the green supply chain. The securing of profitable projects on a continuous basis should be of uppermost importance for a contractor to earn revenues. The structure of the green building sector, more so than the conventional building sector, tends to nurture very close relationships among the supply chain stakeholders, such as the building system owner, building designer, manufacturer and contractor (Dlungwana, 2014). Thus, when crafting a marketing strategy the small contractor should give a serious consideration to the key success factors, such as partnerships building, bidding strategy and competitive strategy. Other key success factors include cost and financial management, risk management, project management and quality management.

The training of green contractors should prioritise the above factors while continuing to take care of other generic business aspects, such as good human resource management, innovation and communication strategy.

### **Skills training and mentorship**

Once the priority development areas have been outlined, the focus should be on structuring a skills development programme for the small contractor that addresses the key success factors through training and mentoring. Training should comprise a strong theoretical component which introduces the green building concepts, principles and practices. The training should be underpinned by the use of user-friendly training manuals and other relevant tools. The theoretical training should be backed by a well-structured mentorship based practical training that is linked to green projects. As advocated by Gibb (1996), learning should not only be theoretical in such a way that is distanced from the context. Learning should be experienced-based in order to be more meaningful to the learner. The proposed framework for skills development should be underpinned by a strong practical learning supported by trained and experienced mentors.

The content of the training programme should be carefully selected to address green building aspects as they pertain to small contractors in the sector. Since the green building is a new field of practice, training programmes put emphasis on communicating new concepts, business strategies and practices effectively to the learners.

### **Alignment of training to enterprise development phases**

Skills development programmes should be relevant to the development phases of the enterprise by ensure that training is packaged appropriately. The enterprise at the start-up phase should not be given high-level training that is suitable for a mature enterprise which has the management systems in place as this may cause confusion and disillusionment to the learners. Similarly, training should be packaged carefully to address the specific needs of the business owner, management and staff. Skills development programme cannot be a silver bullet that hopes to address all the challenges with one approach. There should an effort to tailor training packages accordingly.

### **Support measures for skills development programmes**

The skills development programmes require a set of support measures from a number of green building sector stakeholders. Arguably, the most critical stakeholders are clients and consumers that procure and consume green building products and services. Some of the key support measures entail promotion of green building principles and practices through awareness and educational interventions, procurement measures aimed at promoting good industry practices and making available the resources to implement skills development programmes.

### **Monitoring and evaluation of outputs and impact**

A major component of the skills development framework should comprise an effective

system of monitoring and evaluating assessing whether training produces the intended outputs and impact. The expected range of outputs and impact include green skills for the enterprise's owner, management and staff, enhanced enterprise competitiveness in the market, smart jobs and green products and services.

### **Towards skills development tools**

While the proposed skills development framework incorporates many best practices, it should be accepted that no single framework is suitable to resolve all the skills challenges experienced by the sector.

The sector use this generic framework to design tools tailored for enterprises at different stages of development. Such tools should be packaged to address requirements of people at different levels of the enterprise. Critically, the tools for monitoring and evaluation should be developed to assess progress made by the skills development programme.

### **Conclusion and future research**

This chapter covered a review of literature on the subject of skills development in South

Africa generally and in the local construction sector in particular. Four different types of skills development frameworks prevailing in the traditional building sector were summarised. One framework relating to the green building sector was reviewed. A generic framework for developing contractor skills within the green building sector was also proposed and described.

Future research work is needed to customise the framework for green contractors according to the particular location of the contractor in the green supply chain and according to the development phase of the enterprise. Furthermore, there is need to develop refined skills development tools to address needs of an entrepreneur (strategic level), the management (operational/ tactical level) and the staff (technical level). It is by developing green skills across the green building value chain that we can begin to unlock the real potential for the green building economy.

### **References**

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- Barreira, J., Dhlwayo, S., Luiz, J., Naude, W., Urban, B. 2008. *Frontiers in Entrepreneurship*, Book 1. Ed: Boris Urban. Heinemann Publishers, Johannesburg.
  - International Research Council for Building and Construction (CIB), 2002. *Agenda 21 for Sustainable Construction in Developing Countries*, CIB/UNEP/CIDB/CSIR, Pretoria.
  - construction industry development board (cidb) , 2004. *South African Construction Industry: Status Report*. Pretoria. Accessible at [www.cidb.org.za](http://www.cidb.org.za) . Accessed on 28 September 2017.
  - construction industry development board (cidb), 2007. *Skills for Infrastructure Delivery in South Africa*. Pretoria Accessible at [www.cidb.org.za](http://www.cidb.org.za) . Accessed on 16 September 2017.
  - construction industry development board (cidb), 2009. *Status Quo Report: Contractor Development Programmes*. Pretoria. Accessible at [www.cidb.org.za](http://www.cidb.org.za) . Accessed on 29 September 2017.
  - construction industry development board (cidb), 2011. *Contractor Skills Survey*. Pretoria. Accessible at [www.cidb.org.za](http://www.cidb.org.za) . Accessed on 25 September 2017.
  - Dlungwana, S., 2011. *Case study on managerial skills development project for small contractors in the Eastern Cape province in South Africa*. In: Ben Obinero Uwakweh , Ed. *Innovation*

and

- Sustainable Construction in Developing Countries, 1-3 November 2011, Hanoi, Vietnam. Construction Publishing House, 221-225.
- Dlungwana, W.S., 2014. The supply chain of innovative building technologies in South Africa and opportunities for small and medium-sized enterprises. Dissertation (MSc Degree), University of Pretoria. Pretoria.
- Department of Labour, 2010 National Scarce Skills List. Pretoria.
- Department of Public Works, 2011. Green Building National Framework. Pretoria.
- Gibb, A.A., 1997. Small Firms Training and Competitiveness. Building Upon the Small Business as a Learning Organisation. International Small Business Journal, (1997), 13-29.
- Green Building Council of South Africa (GBCSA), Association of South African Quantity Surveyors (ASAQS), University of Pretoria (UP), 2016. Green Building in South Africa: Guide to Costs and Trends. International Bank for Reconstruction and Development/ The World Bank, 2014. Building Competitive Green Industries: The Climate and Clean Technology Opportunity for Developing Countries. Washington D.C. Available at [www.infodev.org](http://www.infodev.org) Accessed on 25 November 2017.
- International Labour Organisation (ILO), 2010. Skills for Green Jobs in South Africa. Geneva.
- International Labour Office (ILO), 2011. Skills for Green Jobs - A Global View: Synthesis Report Based on 21 Country Studies. Geneva.
- International Labour Organisation (ILO), 2013a. Start and Improve Your Green Construction Business (SIYGCB). Geneva.
- International Labour Organisation (ILO), 2013b. Introduction to green construction: Becoming a green construction enterprise (draft version). Geneva.
- Kraak, A. (2005) Human resource development and the skills crisis in South Africa: the need for a multi-pronged strategy. *Journal of Education and Work*, 18:1, 57-83.
- Lu, W., Shen, I. and Yam, M.C.H., 2008. Critical Success Factors for Competitiveness of Contractors: China Study. *Journal of Construction Engineering and Management*. 134:12, 972-982.
- McGrath, and Akoojee, (2007) Education and skills for the development in South Africa: Reflections on the accelerated and shared growth initiative for South Africa. *International Journal of Educational Development* 27 (2007) 421-434.
- Moss, I., Smallwood, J., 2008. An Investigation of training and mentoring of emerging contractors in the Eastern Cape. *Acta Stuctilia*, 25:2 (2008) 115-125
- NCDP, 2011. Guidelines for Implementing Contractor Development Programmes. Produced by Department of Public Works and the Construction Industry Development Board, September 2011, accessible at [www.cidb.org.za](http://www.cidb.org.za)
- Schumpeter, J.A., 1954. *History of Economic Analysis*. Edited by Elizabeth Boody Schumpeter, New York: Oxford University Press. Also London: George Allen and Unwin (6th Edition, 1967).
- Sustainable Construction Task Group (SCTG), 2002. Reputation, risk and reward: the business case for sustainability in the UK property markets. Accessible at <http://projects.bre.co.uk/rrr/RRR.pdf> Accessed on 16 September 2017.
- Tan, Y., Shen, L. and Yao, H., 2011. Sustainable construction practice and contractors' competitiveness: A preliminary study. *Habitat International* 35(2011) 225-230
- Qongqo, P.N. and Mphahlele, G.K., 2014. An Assessment of the Impact of Public Sector Contractor Development Programmes in South Africa. In Theo Haupt, Ed: 8th Built Environment Asocsa Conference, Durban, South Africa, Asocsa2014-ID12, 188-200.

# Chapter 8

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## Production of metakaolin as a partial cement replacement using a vertical shaft kiln

— N. Dumani and J. Mampiravana



## Introduction

The production of ordinary Portland cement (OPC) is a highly energy-intensive process that releases large amounts of greenhouse gases, mainly carbon dioxide (CO<sub>2</sub>) into the atmosphere (Ramezaniyanpour and Jovein, 2012; Suryawanshi et al., 2015). The manufacture of 1 ton of OPC generates approximately 1 ton of CO<sub>2</sub> into the atmosphere (Rashad and Zeedan, 2011). Globally, the cement industry accounts for approximately 5-7% of total CO<sub>2</sub> emissions (Torgal et al., 2011; Juenger et al., 2011; Krajči et al., 2015). Since CO<sub>2</sub> emissions contribute to global warming, the cement industry has been working on becoming greener through developing low carbon footprint supplementary cementitious materials (SCMs), reducing the content of clinker in cement through partially replacing it with pozzolanic materials (Palomo et al., 1999; El-Diadamony et al., 2016). The partial substitution of OPC with suitable SCMs reduces energy consumption and CO<sub>2</sub> emissions into the atmosphere (Krajči et al., 2015). Besides the environmental benefits, the use of SCMs can significantly enhance the workability, mechanical properties and durability characteristics of concrete in comparison with OPC alone (Razak et al., 2004; Justice, 2005; Dinakar et al., 2013; Rashad, 2013). Currently, common SCMs such as fly ash, slags and silica fume are being extensively used to partially replace cement. However, these materials are subject to geographical availability problems; fly ash is localised in Mpumalanga, slags and silica fume are localised to smelters in Gauteng and North West and thus there is need to find alternative SCM's from local sources that are abundantly and ubiquitously available (Huat, 2006; Antoni et al., 2012).

The use of metakaolin (MK) as a partial OPC replacement has received considerable interest in recent years due to its pozzolanic properties (Wild et al., 1996; Guneyisi and Mermerdas, 2007; Si-Ahmed et al., 2012). The utilisation of MK as OPC partial replacement

increases strength, enhances durability, mitigates alkali-silica reactivity and improves the workability of concrete (Sabir et al., 2001; Guneyisi and Mermerdas, 2007; Siddique and Kadri, 2011; Aiswarya et al., 2013). As a result, metakaolin is increasingly being used to produce high-strength, high-performance concrete (Barbhuiya et al., 2015). In spite of the numerous studies that show the performance, cost and environmental benefits of using MK as a partial replacement of OPC, the wide spread use of MK is still to happen. In the market, MK costs more than OPC and SCMs such as fly ash and slags even though the production of MK involves lower temperatures (Palomo et al., 1999; Vejmelková et al., 2010). A South African company sells MK for R8/kg as an alternative to silica fume.

However, in South Africa MK can be produced in large quantities, as the kaolinic clays that are used to produce MK occur in deposits available far and wide in the country. Locations with abundant kaolinic clays that are suitable for MK production include Makana in the Eastern Cape, Hammanskraal outside Pretoria, Zebediela in Limpopo, Northern Cape and Western Cape, inter alia (Heckroodt, 1991; Heckroodt, 1992; Jacob et al., 2004; Department of Mineral Resources, 2010).

The CSIR has developed a low cost process for the production of metakaolin using a coal-fired vertical shaft kiln (VSK). The development of the VSK process was motivated by the need to produce MK economically - reducing its production cost and ultimately its market price. The VSK process is simpler in design, operation and has a lower capital cost than rotary kiln, flash calciner and multiple-hearth furnace processes that are commonly used to produce metakaolin (USEPA, 1985; Bes, 2006; Edwards, 2011; Okonkwo et al., 2012; Eskelinen, 2014; Eskelinen et al., 2015; Gebremariam, 2015; PEC Consulting, 2015; Teklay et al., 2015). This chapter presents the work that CSIR has done to produce metakaolin as an alternative cementitious material using the VSK

process. This study will summarise the results obtained for the calcination of kaolinitic clays to produce MK using VSK, cost and environmental benefits of producing MK using VSK.

### Properties of metakaolin

MK is a supplementary cementitious material (SCM) used in the cement and concrete industry as partial replacement for Ordinary Portland cement (OPC) in the formulation of blended cements as well as geopolymer binders (Aiswarya et al., 2013; Tironi et al., 2014; Kenne Dikko et al., 2015). Metakaolin not only enhances properties of concrete, but also has environmental benefits (Mikhailenko, 2012). MK contains amorphous aluminosilicate pozzolanic materials that react with portlandite  $\text{Ca(OH)}_2$  or CH in the presence of water at normal temperatures to produce additional calcium silicate hydrates and calcium aluminate hydrates (Razak et al., 2004; Khatib et al., 2014; Boháč et al., 2015). MK consumes the CH - which is one of the by-products of cement hydration and is associated with poor durability - resulting in greatly enhanced concrete durability (Sabir et al., 2001; Guneyisi et al., 2007). Additional calcium silicate hydrates generated by the reaction of CH with MK increase strength of the concrete (Sabir et al., 2001; Aiswarya et al., 2013).

MK differs from other SCMs such as fly ash and slag due to a combination of the filler effect, the ability to accelerate cement hydration and its high reactivity with CH (Wild et al., 1996; Lagier and Kurtis, 2007; Khatib et al., 2014). Concrete incorporating MK exhibits similar performance to that of concrete containing silica fume (Khater, 2010). Silica fume is used to produce high-strength and high-performance concrete. However, due to its localised availability and high price, it can easily be replaced by MK as an alternative SCM where high strength concrete is desired (Velmelková et al., 2010; Dinakar et al., 2013; Khatib et al., 2014).

MK can be used in many aspects of concrete (Siddique et al., 2009):

- High performance, high strength and lightweight concrete
- Pre-cast concrete
- Glass fiber reinforced concrete
- Fibre cement and ferrocement products
- Mortars, grouts, stuccos, plasters

### Production of metakaolin

MK is produced by the controlled de-hydroxylation of kaolinitic clay on calcination. Kaolinite is one of the most abundant natural clay minerals on earth's crust (Ramezani-pour and Jovein, 2012; Nova, 2013; Teklay et al., 2015). Kaolin has traditionally been used in the manufacturing of porcelain and as a coating for paper (Justice, 2005; Huat, 2006; Teklay, 2015). The main constituent of kaolin is kaolinite which is a hydrous aluminium silicate which has a formula  $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$  (Justice, 2005; Huat, 2006; Rashad, 2013; Krajčič et al., 2015). Structurally, kaolinite consists of alumina octahedral sheets and silica tetrahedral sheets stacked alternatively with the theoretical composition of 46.54%  $\text{SiO}_2$ , 39.50%  $\text{Al}_2\text{O}_3$  and 13.96%  $\text{H}_2\text{O}$  (Justice, 2005; Huat, 2006; Rashad, 2013; Teklay, 2015; Krajčič et al., 2015). Kaolinitic clays often contain different impurities such as quartz, mica, feldspar and rutile (Justice, 2005; Rashad, 2013) that are derived from the chemical weathering of granitic source rocks.

Under normal conditions, kaolinite is stable and will not react chemically with calcium hydroxide to produce cementitious materials (Justice, 2005; Huat, 2006; Rashad, 2013; Shan et al., 2016). However, when heated to temperatures 600-800°C, kaolin loses 13.96% structural water (Sabir et al., 2001; Justice, 2005; Krajčič et al., 2015; Shan et al., 2016). This thermal treatment or calcination breaks down the structure of kaolinite resulting in disordered (amorphous) alumina and silica layers producing a highly reactive MK that is suitable for use in cement applications (Kurtis, 2011; Nova, 2013; Aiswarya et al., 2013; Rashad, 2013; Krajčič et al., 2015; Shan et al., 2016). When

the temperature is increased beyond 800°C, the MK undergoes de-silication reactions forming crystalline phases – first spinel sensu lato is formed and it is finally converted into mullite and cristobalite (Teklay et al., 2015; El-Diadamony et al., 2015). The presence of high levels of the crystalline phases will cause a decline in pozzolanic reactivity of the MK (Sabir et al., 2001; Teklay, 2015). The heating process is illustrated by differential thermal analysis (DTA) in Figure 1.

Unlike other pozzolanic materials such as fly ash and silica fume, MK can be produced under controlled conditions to achieve the desired properties (Poon et al., 2006; Barbhuiya et al., 2015). As such, calcination parameters such as calcination temperature, residence time, particle size can be optimised to obtain high pozzolanic reactivity.

### Method of calcination

Commonly, the calcination of kaolinitic clay to produce metakaolin can be carried out using a rotary kiln, flash calciner and multiple-hearth furnace on industrial scale. Calcination of kaolinitic clay is conventionally carried out in rotary kilns to produce metakaolin (Justice, 2005). Kaolin clay is heated in the range 650-700°C for about 3 to 5 hours during which the metakaolin is agglomerated into 5 to 10 cm pellets (Nicolas et al., 2013). While in a flash calciner, the kaolin is heated rapidly at 103-105 °C per second and held within the temperature range 1000 -1200°C for a short time (Nicolas et al., 2013), usually 0.5 to 1 second (Teklay, 2015) and cooled. However, these processes are capital intensive and complex thereby increasing the price of metakaolin.

Traditionally, the VSK process is used for the calcination of limestone to produce lime. Vertical shaft kilns are fuel-efficient (Hassibi, 2002). Fuel efficiencies of the order of 80% are achievable in well-designed vertical shaft kilns (Okonkwo et al., 2012; PEC Consulting, 2015). Moreover, the VSK process is simpler in design, has lower capital cost and lower operating

costs than the other processes, thus more jobs can be created far and wide for a given amount of available capital (USEPA, 1985; Bes, 2006; Edwards, 2011; Okonkwo et al., 2012; Eskelinen, 2014; Eskelinen et al., 2015; Gebremariam, 2015; PEC Consulting, 2015; Teklay et al., 2015).

### Methodology

The CSIR has developed a low cost process for the production of metakaolin using VSK. The VSK process requires specific operating parameters (clay lump size and distribution, coal particle size, clay: coal ratio, kiln height: diameter ratio, temperature profile, and charge bed thickness and residence time). Initially, an electric furnace under very strict controlled conditions in the laboratory was used to determine optimized calcination parameters such as clay particle size, calcination temperature and residence time.

The laboratory optimized parameters for the production of MK were scaled up to a 3.2 ton per day coal-fired pilot VSK where the effect of coal to clay ratio and the charge bed thickness were investigated. Lumps of kaolinitic clay and optimal amount of coal pebbles were mixed and fed into the VSK from the top with different bed thickness depending on the clay: coal ratio. The bed thickness for each layer was chosen such that the material can burn through over the required resident time to achieve full metakaolinisation without over calcination. Metakaolin was discharged from the bottom of the VSK at regular times. Various grades of MK from different charge bed thickness were produced and characterized in order to determine the optimum VSK process parameters for the production of MK. Finally, using the optimised process parameters obtained from the 3.2 ton per day VSK, the production of MK was demonstrated on a 12 ton per day semi-industrial kiln (see Figure 2). High grade kaolinitic clay containing 95% kaolinite was calcined in all cases.

The production cost of MK using the VSK was estimated using the price of coal, fuel efficiency of 3.2 ton per day VSK and ball milling

cost and thus was used to approximate the retail price of MK. The carbon footprint of MK produced using VSK was determined using the LCA software tool SimaPro 8.1 with Ecoinvent Database version 3.

### Production of metakaolin from kaolinitic clays results

The CSIR has successfully produced MK from kaolinitic clays, initially using an electric furnace and then semi-industrially using coal-fired vertical shaft kilns (VSKs). The metakaolins produced differed in the amounts of amorphous content. Calcination of kaolinitic clay using an electric furnace produced metakaolin with an amorphous phase (MK) content of 94% by weight while from the 3.2 ton per day VSK the optimum operating conditions produced MK with an amorphous phase (MK) content of 91% by weight. Lastly, the highest grade of MK produced on a 12 ton per day semi-industrial



kiln had an amorphous phase (MK) content of 81% by weight. The CSIR determined VSK process parameters are proprietary.

### Cost analysis of vertical shaft kiln metakaolin production

The production cost of MK using the VSK process was estimated. The 3.2 ton per day VSK used had a fuel efficiency of only 23%.

- Coal price of R2000/ton was used
- Cost of coal required to calcine 1 ton kaolin clay to produce 0.88 tons of MK was  $R2000/8.5 = R235$  at 23% VSK efficiency
- Therefore, cost to produce 1 ton MK =  $R235/0.88 = R267$
- Ball mill grindability of the MK for 90% passing  $75\mu\text{m}$  was obtained to be 53kWh/ton. Assuming electrical energy cost of R1.50/kWh, the ball milling cost for the metakaolin =  $R1.50 \times 53 / \text{ton} = R79.5/\text{ton}$
- Thus, the total specific energy cost for the production of metakaolin =  $R267 + R79.5 = R346.5/\text{ton}$ .
- Comparing the above cost to the current retail price of CEM I that varies between R1200 - R1680 per ton depending on supplier, the production cost of MK is much lower and thus the retail price of MK is expected to be lower for the same mark-up. 50% weight substitution of CEM I by MK, will reduce the price of blended cement to between R783 and R1023 per ton –significantly lower than the current ex-works market prices of CEM I cement.

Development of MK as a partial cement replacement using VSK process resulted in manufacture of cheaper but higher performance cement blends than corresponding OPC based concretes with 28 day compressive strength > 90 MPa (Mapiravana, J). More than 80% of the 28 day compressive strength was achieved within only 14 days (Mapiravana, J). MK-based building

Figure 2: The 12 ton per day semi-industrial VSK



materials can therefore be used to build more infra-structure such as housing for less.

### Environmental benefits of vertical shaft kiln process

The partial substitution of OPC with MK reduces energy consumption of cement production and CO<sub>2</sub> emissions into the atmosphere. The LCA software tool SimaPro 8.1 with Ecoinvent Database version 3 was used to determine CO<sub>2</sub> emissions associated with production of OPC, extraction and crushing of kaolin clay and transportation.

The CO<sub>2</sub> emissions that arose from burning coal were obtained using a carbon emission factor of 2.8814 kg CO<sub>2</sub>eq/kg. The carbon emission factor was obtained by using CO<sub>2</sub> emission factor from Eskom of 1.03 CO<sub>2</sub>eq/kWh (Nova Institute Carbon Calculator). The obtained factor was then compared with the emission factor of bituminous coal in the USA which was found to be 2.325 kg CO<sub>2</sub>eq/kg (EPA, 2014). It was observed that the factor in SA is higher than the one used in the USA and this was attributed to the fact that the coal in SA is dirtier than that used in most countries.

The CO<sub>2</sub> equivalence of metakaolin was obtained to be 0.415 kgCO<sub>2</sub>eq/kg metakaolin as shown in Table 1. Similar results were reported by Heath et al. (2014), NLK (2002) and Jones et al. (2011) with values of 0.423 kgCO<sub>2</sub>eq/kg, 0.370 kgCO<sub>2</sub>eq/kg and 0.330 kgCO<sub>2</sub>eq/kg respectively. It was concluded from the results in Table 1 that the carbon footprint of

the MK was only 43% of that for OPC at a VSK efficiency of only 23%. The results in Table 1 show that the VSK process significantly reduced CO<sub>2</sub> equivalence of cement (1000 kg/ton) by producing a lower carbon footprint cement extender with a CO<sub>2</sub> equivalence of 415 kg/ton. The MK was used to partially replace OPC beyond 90% by weight (Mapiravana, J) depending on the application. It was established that the carbon footprint of the MK can be improved through better VSK insulation and flue gas energy recuperation.

The actual energy required for complete dehydroxylation of the kaolinitic clay was obtained from the DSC area under the dehydroxylation endothermic hump per unit weight of clay as shown in Figure 3.

The VSK fuel efficiency was computed as percentage of the actual energy required for dehydroxylation to the energy available from the coal used for calcination of the same unit weight of kaolin clay. Figure 4 shows that further significant reductions of CO<sub>2</sub> equivalence can be achieved by increasing the VSK fuel efficiency.

### Conclusion

CSIR has successfully produced MK with a high amorphous MK content using a semi-industrial coal-fired VSK. A lower carbon equivalence MK product was produced when compared to OPC; lower VSK process cost in comparison to OPC and the simplicity of the VSK process were demonstrated.

Material	kg CO <sub>2</sub> eq/kg	
Metakaolin	Coal	0.375
	Kaolin clay	0.00362
	Transport	0.036
	Total	0.415
Ordinary Portland cement	0.973	

Table 1: Comparison of carbon equivalence of the VSK metakaolin with Ordinary Portland Cement

### Future Work

The next step is to modify the VSK kiln design and construction to improve energy efficiency and to further reduce the carbon equivalence and cost of the MK product. The

next development will also demonstrate the production of MK using a 30 – 100 ton per day industrial VSK kiln to produce sufficient MK/ cement blends for commercialization.

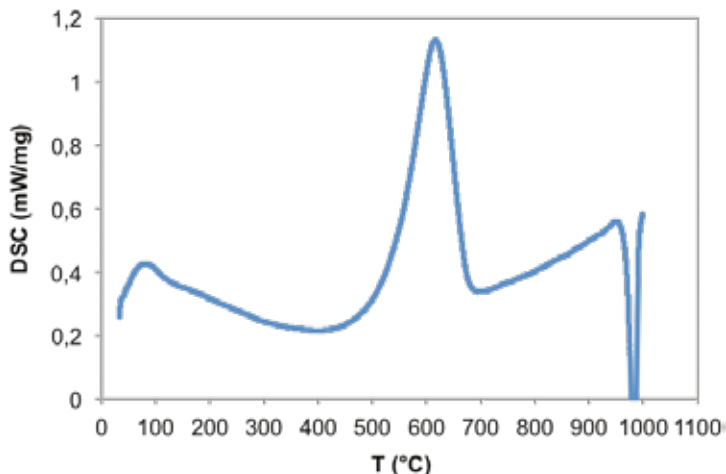


Figure 3: DSC thermogram of the raw kaolinic clay. NB. Hump implies endothermic reaction and a trough implies exothermic reaction

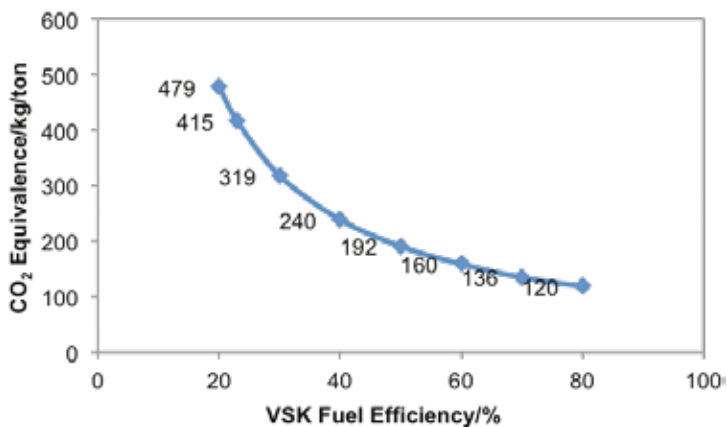


Figure 4: Calculated CO<sub>2</sub> equivalence of metakaolin produced by the VSK process as a function of VSK fuel efficiency

## References

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- Aiswarya, S., Arulraj, P.G., and Dilip, C., 2013, A review on use of metakaolin in concrete. *Engineering Science and Technology: An International Journal (ESTIJ)* 3(3), 592-597
- Antoni, M., Rossen, J., Martirena, F., and Scrivener, K., 2012, Cement substitution by a combination of metakaolin and limestone. *Cement and Concrete Research* 42, 1579-1589
- Barbhuiya, S., Chow, P., and Memon, S., 2015, Microstructure, hydration and nano-chemical properties of concrete containing metakaolin. *Construction and Building Materials* 95, 696-702
- Bes, A., 2006, Dynamic process simulation of limestone calcination in normal shaft kilns. PhD thesis. Otto-von-Guericke-University, Magdeburg
- Boháč, M., Novotný, R., Frajkorová, F., Yadav, R.S., Opravil, T., and Palou, M., 2015, Properties of cement pastes with different particle size fractions of metakaolin. *World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering* 9(4), 293-297
- Department of Mineral Resources, 2010, Ceramic Industry in South Africa report
- Dinakar, P., Sahoo, P.K., and Sriram, G., 2013, Effect of metakaolin content on the properties of high strength concrete. *International Journal of Concrete Structures and Materials* 7(3), 215-223
- Edwards, L., 2011, Quality and process performance of rotary kilns and shaft calciners. TMS (The Minerals, Metals and Materials Society) *Light Metals*, 895-900
- El-Diadamony, H., Amer, A.A., Sakkary, T.M., and El-Hoseny, S., 2016, Hydration and characteristics of metakaolin pozzolanic cement pastes. *Housing and Building National Research Center (Article in Press)*, 1-9
- EPA, 2014, Emission factors for Greenhouse Gas Inventories. [Online] available from: [https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors\\_2014.pdf](https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf), [accessed: 09 November 2016]
- Eskelinen, A., 2014, Dynamic modelling of a multiple hearth furnace. PhD thesis. Department of Biotechnology and Chemical Technology, Aalto University School of Chemical Technology
- Eskelinen, A., Zakharov, A., Jämsä-Jounela, S-S., and Hearle, J., 2015, Dynamic modelling of a multiple hearth furnace for kaolin calcination. *AIChE Journal* 61(11), 3683-3698
- Gebremariam, A.T., 2015, CFD modelling and experimental testing of thermal calcination of kaolinite rich clay particles – an effort towards green concrete. PhD thesis. Department of Energy Technology, Aalborg University
- Guneyisi, E., and Mermerdas, K., 2007, Comparative study on strength, sorptivity, and chloride ingress characteristics of air-cured and water-cured concretes modified with metakaolin. *Materials and Structures* 40, 1161-1171
- Hassibi, M., 2002, Factors affecting the quality of quicklime (CaO) – from mining to manufacturing to usage, [Online] available from:

- <http://www.chemcosystems.net/Files/Admin/Publications/Factors%20Affecting%20the%20Quality%20of%20Quicklime.pdf>, [accessed: 05 August 2016]
- Heath, A., Paine, K., and McManus, M., 2014, Minimising the global warming potential of clay based geopolymers. *Journal of Cleaner Production* 78, 75-83
- Heckroodt, R.O., 1991, Clay and clay materials in South Africa. *Journal of the Southern African Institute of Mining and Metallurgy* 91(10), 343-363
- Heckroodt, R.O., 1992, Kaolin resources of the Republic of South Africa. *Handbook of the Geological Survey* 13, Republic of South Africa
- Huat, O.C., 2006, Performance of concrete containing metakaolin as cement replacement material. MSc thesis. Universiti Teknologi Malaysia
- Jacob, R.E., Mitha, V.R., and MacPherson, D., 2004, The kaolinic clay deposits on Beaconsfield, north of Grahamstown. *South African Journal of Science* 100, 560-564
- Jones, R., McCarthy, M., Newlands, M., 2011. Fly ash route to low embodied CO<sub>2</sub> and implications for concrete construction. In: *World of Coal Ash (WOCA) Conference*, Denver, Co, USA.
- Juenger, M.C.G., Winnefeld, F., Provis, J.L., and Ideker, J.H., 2011, Advances in alternative cementitious binders. *Cement and Concrete Research* 41, 1232-1243
- Justice, J.M., 2005, Evaluation of metakaolins for use as supplementary cementitious materials. MSc thesis. Georgia Institute of Technology
- Kenne Diffo, B.B., Elimbi, A., Cyr, M., Dika Manga, J., and Tchakoute Kouamo, H., 2015, Effect of the rate of calcinations of kaolin on the properties of metakaolin-based geopolymers. *Journal of Asian Ceramic Societies* 3, 130-138
- Khater, H.M., 2010, Influence of metakaolin on resistivity of cement mortar to magnesium chloride solution. *Ceramics – Silikáty* 54, 325-333
- Khatib, J.M., Negim, E.M., and Yeligbayeva, G.ZH., 2014, Strength characteristics of mortar containing high volume metakaolin as cement replacement. *Research and Reviews in Materials Science and Chemistry* 3(1), 85-95
- Krajčí, L., Mojumdar, S.C., Janotka, I., Puertas, F., Palacios, M. and Kuliffayová, M., 2015, Performance of composites with metakaolin-blended cements. *Journal of Thermal Analysis and Calorimetry* 119, 851-863
- Kurtis, K.E., 2011, Benefits of metakaolin in HPC. *HPC Bridge Views*, Issue 67, 6-9
- Mapiravana J, Private communication on High Performance MK /cement blends
- Mikhailenko, P., 2012, Durability of cement paste with metakaolin. MSc thesis. Ryerson University, Toronto
- Nicolas, R.S., Cyr, M., and Escadeillas, G., 2013, Characteristics and applications of flash metakaolins. *Applied Clay Science* 83-84, 253-262
- NLK, 2002, Ecosmart Concrete Project: Metakaolin Pre-feasibility Study. NLK Consultants Inc., Vancouver, Canada.
- Nova, J., 2013, Strength properties of metakaolin admixed concrete. *International Journal of Scientific and Research Publications* 3(6), 1-7
- Okonkwo, P.C., Adefila, S.S., and Beecroft G.A., 2012, Fundamental approach to the design of single vertical shaft lime kiln. *International Journal of Engineering Research and Applications* 2(2), 70-78
- Palomo, A., Blanco-Varela, M.T., Granizo, M.L., Puertas, F., Vazquez, T., and Grutzeck, M.W., 1999, Chemical stability of cementitious materials based on metakaolin. *Cement and Concrete Research* 29, 997-1004

- PEC Consulting, 2015, Selecting the proper lime kiln Technology. [Online] available from <http://pecconsultinggroup.com/newsflash/lime-kiln-technology>, [accessed: 06 February 2017]
- Poon, C.S., Kou, S.C., and Lam, L., 2006, Compressive strength, chloride diffusivity and pore structure of high performance metakaolin and silica fume concrete. *Construction and Building Materials* 20, 858-865
- Ramezani-pour, A.A., and Jovein, H.B., 2012, Influence of metakaolin as supplementary cementing material on strength and durability of concretes. *Construction and Building Materials* 30, 470-479
- Rashad, A.M., and Zeedan, S.R., 2011, The effect of activator concentration on the residual strength of alkali-activated fly ash pastes subjected to thermal load. *Construction and Building Materials* 25, 3098-3107
- Rashad, A.M., 2013, Metakaolin as cementitious material: History, sources, production and composition – A comprehensive overview. *Construction and Building Materials* 41, 303-318
- Razak, H.A., Chai, H.K., and Wong, H.S., 2004, Near surface characteristics of concrete containing supplementary cementing materials. *Cement & Concrete Composites* 26, 883-889
- Sabir, B.B., Wild, S., and Bai, J., 2001, Metakaolin and calcined clays as pozzolans for concrete: a review. *Cement and Concrete Composites* 23, 441-454
- Shan, C.S., Rijuldas, V., and Aiswarya, S., 2016, Effects of metakaolin on various properties of concrete – an overview. *International Journal of Advanced Technology in Engineering Science* 4(1), 237-245
- Si-Ahmed, M., Belakrouf, A., and Kenai, S., 2012, Influence of metakaolin on the performance of mortars and concretes. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering* 6 (11), 1010-1013
- Siddique, R., and Kadri, E., 2011, Effect of metakaolin and foundry sand on the near surface characteristics of concrete. *Construction and Building Materials* 25, 3257-3266
- Suryawanshi, Y.R., Kadam, A.G., Ghogare, S.S., Ingale, R.G., and Patil, P.L., 2015, Experimental study on compressive strength of concrete by using metakaolin. *International Research Journal of Engineering and Technology* 2(2), 235-239
- Teklay, A., 2015, CFD modelling and experimental testing of thermal calcination of kaolinite rich clay particles: an effort towards green concrete, PhD thesis, Aalborg University, Denmark
- Teklay, A., Yin, C., and Kohler, L.L., 2015, Experimental and modelling study of flash calcination of kaolinite rich clay particles in a gas suspension calciner. *Applied Clay Science* 103, 10-19
- Tironi, A., Trezza, M.A., Scian, A.N., Irassar, E.F., 2012, Kaolinitic calcined clays: Factors affecting its performance as pozzolans. *Construction and Building Materials* 28, 276-281
- Torgal, F.P., Shasavandi, A., and Jalali, S., 2011, Using metakaolin to improve the compressive strength and the durability of fly ash based concrete. *INVACO2: International seminar, Innovation & Valorization Civil Engineering & Construction Materials*
- USEPA, 1985, Calciners and dryers in Mineral Industries – background information for proposed standards. [Online] available from <https://nepis.epa.gov>, [accessed: 06

February 2017]

- Velmelková, E., Pavlíková, M., Keppert, M., Keršner, Z., Rovnaníková, P., Ondráček, M., Sedlmajer, M., and Černý, R., 2010, High performance concrete with Czech metakaolin: Experimental analysis of strength, toughness and durability characteristics. *Construction and Building materials* 24, 1404-1411
- Wild, S., Khatib, J.M., and Jones, A., 1996, Relative strength, pozzolanic activity and cement hydration in superplasticised metakaolin concrete. *Cement and Concrete Research* 26(10), 1537-1544

# Chapter 9

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## A Review of the Role of Science, Technology and Innovation in Sustainable Human Settlements and Housing Policy

— Department of Science and Technology

## Background and Context

The Department of Science and Technology undertook a review of the role of science, technology and innovation in sustainable human settlements and housing policy in South Africa. The review aimed at strengthening science, technology and innovation in human settlement formation by, inter alia, benchmarking the uptake of innovative building technologies, evaluates whether the South African Government's sustainable human settlement policy adequately recognises and supports the application of Science, Technology and Innovation (STI) in the realisation of sustainable human settlements and, if not, how this policy gap should be addressed.

Contemporary literature on human settlements in the 21st century indicates that there are economic, social, environmental, political, technological and human behavioural shortcomings in human settlement formation theory and practice. These shortcomings arise out of a failure to acknowledge that human settlements operate within complex systems and are multifunctional in nature requiring a multifunctional, trans- and interdisciplinary approach to improve livelihoods in an equitable, economically, socially and environmentally sustainable manner.

This review is framed against Government's resolution in August 2013 to progressively increase the uptake of Innovative Building Technologies (IBT) in the public sector's social infrastructure delivery programme in order to reduce building costs, improve building quality and performance, create new decent jobs, improve skills development, support the Industrial Policy Action Plan (IPAP), and support a transition towards the Green Economy. This review is primarily aimed at reviewing the role of STI in accelerating the development of sustainable human settlements in South Africa: thus the review is done through the primary lens of 'sustainability', and the secondary lens of 'sustainable human settlements'. To guide the review process the study has relied on

the triple bottom line classically used in sustainability considerations namely, economic viability, social well-being and environmental stewardship.

## Science-based policy

Policy can be described as "a course or principle of action, adopted or proposed by a government, party, business or individual" (The Concise Oxford Dictionary 1982:793). Although interpreted in many different ways, some features are common to all good policy, namely:

- It states matter of principle
- It is focused on action, stating what is to be done and by whom
- It is an authoritative statement, made by a person or body with power to do so

Fundamental to good policy is its ability to make administration easier, and to allow officials to get on with the organisations core business more efficiently and effectively. To do this policy should assist decision-makers in both subjective and objective decision making. Subjective decision making relates to those decisions where the relative merits of a number of factors are to be considered and trade-offs identified before a decision is made: in this case, the relevant policy is to establish unambiguous principles that are to be applied in the assessment. Objective decision making relates to those decisions that are usually operational in nature. In both instances, policy must guide actions toward those that are most likely to achieve the desired outcome.

Increasingly therefore calls are made for science to be integrated into policy development under the banner of 'science for policy' or 'evidence-based policy' (EBP) and that relevant policies should take into account both scientific knowledge and the needs of science (Head 2001:17).

Science-based institutions can contribute to policy development in three areas (ICSU 2014):



- i) Providing scientific advice and coordinating the participation of scientists in policy processes;
- ii) Providing advice on how policy processes should be created or modified to best receive and utilise available science knowledge; and
- iii) Creating scientific research programmes that will improve collaboration between scientists, policy-makers and other stakeholders in the generation of scientific knowledge.

### **Sustainable human settlements within the South African context**

In reality our current human settlement patterns were not conceived with sustainability in mind: most South Africans live in transport-dependent suburbs/townships resulting in a high-carbon lifestyle with a number of concomitant challenges. These challenges include increases in poverty; unemployment (particularly among the youth); high costs of infrastructure development (transportation, electricity, sanitation, water), operation and maintenance; diminishing affordability; few job opportunities; deteriorating public health; and poor environmental quality. Infrastructural, programmatic, and technological changes need to be integrated into new developments while existing settlements need to be retrofitted so that settlements increasingly and rapidly become low-carbon, affordable, and healthy places (Ecobuildingpulse 2014).

### **Science, technology and innovation**

A nation's ability to solve problems and initiate and sustain economic growth depends to some extent on its capabilities in science and technology (Millennium Project 2004). Science and technology has been shown to be linked to economic growth (Global Commission 2014:45), and certainly, the ability to provide clean water, health care, infrastructure, and healthy food all have a component that includes science and technology.

Science, technology and innovation (STI) is intended to refer to the application of all types

of scientific and technological innovations, as well as associated institutional adjustments, to the advancement of the country. STI can thus be used to include all forms of useful knowledge derived from diverse branches of learning and practice ranging from basic scientific research to engineering to traditional knowledge.

Eco-innovation is one of the key enabling instruments identified by the EU for the transition to a more resource efficient economy (UNEP 2014:3). Eco-innovation is the development of products and processes that contribute to sustainable development, applying the commercial application of knowledge to elicit direct or indirect ecological improvements ranging from environmentally friendly technological advances to socially acceptable innovative paths towards sustainability (James 1997). Because eco-innovation focuses more on usage than product it introduces a governance component that makes eco-innovation a more integrated tool for sustainable development.

### **The science, technology, innovation and sustainable human settlement nexus**

From the previous sections it is clear that science, technology and innovation can and must play a more significant role in achieving sustainable human settlements. The UN Division for Sustainable Development (UN 2013:1) however notes that sustainability policy frameworks have received limited direct science input: there were no scientists on the World Commission on Environment and Development, little science present at the Earth Summit in Rio de Janeiro in 1992, and some scientific presence at the Johannesburg World Summit on Sustainable Development. The report does however note that science was "very prominent" at the Rio+20 UN Conference on Sustainable Development in 2012 and submits that one reason for this is the emergence of sustainability science.

The emergence of sustainability science in the late 2000s and the more recent emergence of city science points to a more intense

participation of the science community in human settlement formation.

## Discussion

As stated in the beginning of this document the purpose of this review is to determine to what extent science, technology and innovation (STI) can support sustainable human settlement formation.

The review finds that the science, technology and innovation/sustainable human settlements nexus is very poorly conceptualised and articulated in national human settlement policy documents. More critically, this review finds that references to STI in the policies reviewed generally address the subject in the context of policy advice for the science system, rather than science advice for public policy.

The review has referenced a large number of documents addressing sustainability and referencing goals, indicators and targets. A large part of the difficulty in achieving 'sustainability' has to do with the conceptual difficulties. There are at least three fundamental flaws in contemporary sustainability thinking and practice that is undermining a sustainable development pathway:

i) Sustainability is a steady state: this view holds that providing certain preconditions are met (meeting the needs of the present generation in manner that enables future generations to meet their own needs) favourable conditions will prevail indefinitely. The recent shift in thinking towards 'resilience' comes on the back of contemporary experience which confirms that the earth is and has always been in a dynamic state oscillating between periods of calm and periods of extremes (the past five extinctions serve as a prime example). Resilience thinking emphasises that sustainability is only achievable if systems are resilient in a dynamic state: resilience is a precondition for sustainability.

ii) Sustainability and resilience are indicators of quality: recent experience in decade-old areas of conflict (Damascus,

Baghdad, Donetsk, Kiev, Kharkiv, Kabul to name a few) demonstrates that even though these cities show remarkable resilience and are demonstrating a stubborn level of sustainability, the quality of life is extremely poor. While sustainability and resilience are precursors for the continuation of life, significant additional and supporting interventions are required to lead to an improvement in the quality of life.

iii) Sustainability is an immediate outcome: because of the above, sustainability has proved to be significantly and frustratingly elusive thus far. Contemporary thinking around achieving sustainability holds the view that what governments can do is set the course toward sustainability by selecting the appropriate waypoint(s) i.e. the policy framework; setting the course to the first waypoint, i.e. consistent implementation; and ensuring that the course is maintained, i.e. measurement.

The review finds that it is necessary to create an enabling environment for science, technology and innovation in the formation of sustainable human settlements. Given the large capital costs, uncertain market conditions and high risks the private sector is unlikely to develop and deploy technologies as required: government will have to play a central role in removing obstacles to the emergence of breakthrough technologies (UNDP 2007:143). Sustainable human settlement is a cross-cutting theme and as such many government departments have a mandated role to play.

The review finds that it is necessary to develop a science, technology and innovation pathway towards sustainable human settlements. Although South Africa's infrastructure is largely fit-for-purpose, the Global Green Economy Index confirms that the infrastructure is environmentally negative. Unfortunately this circumstance will continue unless an alternative growth trajectory is adopted.

One way of changing course is to link STI outcomes to the development of new processes, systems, and products with a focus

on the most fundamental problems and challenges relating sustainability (sustainability science), to cities (city science) and buildings (building science). Innovation, and especially eco-innovation, will be the differentiator in this case. This will establish a pathway for the creation and continued improvement of sustainable, high performance cities and buildings.

## Conclusions

Of all the challenges we face as a nation and as a planet, few are as pressing as the three-pronged challenge of climate change, sustainable development and the need to foster new and cleaner sources of energy, water and sanitation. A massive transformation in our human development approach is required if the promise of sustainability is to become a reality to future generations. This transformation will

have to be based on sound science, and be given effect through eco-innovation.

Although our current scientific understanding can provide us with a fundamental sense of the types of impacts to be expected there is still a significant amount of uncertainty associated with climate change and therefore with its impacts. Precisely because of this, uncertainty needs to be incorporated into the modelling tools, policy-making and decision-making processes.

Considerable gains can cost-effectively be made to set human settlements on a sustainable pathway. These can be achieved through largely already available technologies and practices, which will not only support the transition to a low carbon world but also generate economic, social and environmental co-benefits.

## References

- Ecobuildingpulse 2014. Sustainable communities: retrofitting suburbia for 21st century challenges, [Online] Available from: [http://www.ecobuildingpulse.com/green-building/sustainable-communities-ellen-dunham-jones\\_o.aspx?dfpzone=v2020.sustainablecommunities](http://www.ecobuildingpulse.com/green-building/sustainable-communities-ellen-dunham-jones_o.aspx?dfpzone=v2020.sustainablecommunities) [Downloaded: 2014-11-05].
- Global Commission on the Economy and Climate 2014. Better growth, better climate: synthesis report. [Online] Available from: <http://newclimateeconomy.report/TheNewClimateEconomyReport.pdf> [Downloaded: 2015-02-09].
- Head, B. 2009. Evidence-based policy: principles and requirements. [Online] Available from: [http://www.pc.gov.au/\\_\\_data/assets/pdf\\_file/0007/96208/03-chapter2.pdf](http://www.pc.gov.au/__data/assets/pdf_file/0007/96208/03-chapter2.pdf) [Downloaded: 2015-01-15].
- ICSU 2014. Synthesis report: science advice to government's conference. [Online] Available from: <http://www.icsu.org/publications/reports-and-reviews/synthesis-report-of-the-science-advice-to-governments-conference-2014/synthesis-report-pdf> [Downloaded: 2015-01-09].
- James, P. 1997. "The sustainability circle: a new tool for product development and design". *Journal of Sustainable Product Design* 2:52-57.
- MillenniumProject (2004). Interim Report of Task Force 10 on Science, Technology and Innovation. New York: UN Secretary-General and UN Development Group.
- The Concise Oxford Dictionary 1982:793.
- United Nations 2013. General assembly opens its 68th session with long-term development a prime goal, [Online] Available from: [http://www.ecobuildingpulse.com/green-building/sustainable-communities-ellen-dunham-jones\\_o.aspx?dfpzone=v2020.sustainablecommunities](http://www.ecobuildingpulse.com/green-building/sustainable-communities-ellen-dunham-jones_o.aspx?dfpzone=v2020.sustainablecommunities) <http://www.un.org/apps/news/story.asp?NewsID=45868&Cr=general+assembly&Cr1=#.UjigE-casiSq> [Accessed: 2013-09-20].
- UNDP 2007. Human development report 2007/2008, New York: Palgrave Macmillan.

# Chapter 10

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## A framework for selecting appropriate Innovative Building Technologies (IBTs) for social infrastructure projects

— Department of Science and Technology



## INTRODUCTION

The promotion and use of Innovative Building Technologies (IBTs) to achieve sustainability within the construction sector has been part of the United Nations (UN) environmental movements discourse since the late 1960s (ISOCARP, 2016). In 1992, the Agenda 21 highlighted the use of innovation in materials and technologies as an opportunity for sustainable construction in developing countries (Du Plessis, 2002). It described innovative technologies as “those [technologies] that respond to the local environment, resources and economic needs” (Du Plessis, 2002: 39). This description suggests that the use of alternative technologies is able to assist with not only technological aspects, but also with the creation of economically active, socially responsible and environmentally friendly human spaces (Du Plessis, 2002). The Habitat Agenda, in 1996, furthered these aims in supporting the “development of environmentally sound and affordable construction methods and the production and distribution of building materials, including strengthening the indigenous building materials industry, based as far as possible on locally available resources” (UN, 2003). In 2016 Urban Agenda, Heads of State and Government, Ministers and High Representatives committed to ensuring that the sustainable infrastructure developed in their countries would not only be climate-resilient forming part of integrated urban and territorial development plans, but that in its implementation they would consider, among other things, “innovative, resource efficient, ...context specific ...solutions” (ISOCARP, 2016).

As a signatory of these documents, it is not surprising that the South African Government (through the Presidential Infrastructure Coordinating Commission (PICCC)) has committed to the progressive adoption and use of IBTs. To this end, it has set a target of constructing approximately two thirds of all new social infrastructure projects with IBTs by 2017 (Burger, 2014). The social infrastructure

includes clinics, schools and student accommodation.

IBTs are not covered by the building standards in the National Building Regulations (NBR). In compliance with the deemed-to-satisfy rules as set out in the NBRs, the use of IBTs can only be approved subject to an approved rational design prepared by an approved competent person, or they must be Agrément certified (Keuter, 1977). The National Home Builders Registration Council (NHBC) and Agrément South Africa (SA) are key supporters in this endeavour, this will ensure fitness-for-purpose.

The Agrément SA database currently has hundreds of active certificates, each falling within one of sixteen different categories (2014). This suggests that the identification and ultimate selection of appropriate IBTs will be challenging for decision-makers responsible for the approval of materials in various social infrastructure projects. Such decisions are typically left to the “late design or pre-construction stages due to a lack of knowledge” (Pan et al., 2008, p. 62). The late or wrong decisions taken early in the project development process are concerning, as they may have a far-reaching negative impact later on in the life cycle of such projects.

In addition to the timing of decision-making, it is also important that the decisions made concerning IBTs, should not be based on the instinct or past experience of decision-makers (Pan et al., 2008), particularly when they do not have expertise. Decision support is therefore required to assist decision-makers on this regard. Such support will structure the decision-making process, improving the quality of information on which decisions are based.

The decision-support tool was written in response to a request from the Department of Science and Technology (DST) as part of its mandate to support the uptake of innovation. The Decision Support Tool is for the selection of Innovative Building Technologies (IBTs) in the delivery of South African social infrastructure. The development of this framework was

initiated and funded by the Department of Science and Technology

### **Purpose of the chapter**

This chapter provides an overview of the Framework for the Decision-Support Tool that will, not only inform decision-makers of Agrément SA certified IBTs, but also assist them in selecting appropriate IBTs within the contexts of their social infrastructure projects.

### **Scope of the chapter**

As previously stated, there are currently sixteen categories of active certificates. The Framework for the Decision-Support Tool presented will be limited to the active certificates listed in two Agrément SA database product categories, these are the Walling and Building Systems and Sanitation.

### **Outline of the chapter**

The chapter reviews selected assessment frameworks and then compares their criteria with the Agrément SA's performance criteria. It then presents the Framework for the Decision-Support Tool and how this may be applied. The chapter concludes and with recommendations further development.

### **Selected decision support tools**

The selection of appropriate technologies within the built environment is a concern for numerous researchers (Parr and Shaw, 1999; Du Plessis and Duncker, 2000; Macleod, 2003; Natividade-Jesus, Coutinho-Rodrigues and Antunes 2007; Palaniappan, Gleick and Change 2008; Pan, Gibb and Dainty 2008; Ewing and Baker, 2009; Jadid and Badrah, 2012; Mema, n.d.; Odhiambo and Wekesa, 2010; Pearce, Hastak and Vanegas n.d.). To address this, many have developed various decision support tools/systems to addressing this issue. Due to their relevance to this study, Macleod (1993) and Parr and Shaw (1999) studies were reviewed further and compared with Agrément SA's performance criteria.

In their study, Parr and Shaw (1999) use criteria to assess the appropriateness of water supply technologies to remove nitrate from drinking water with the surrounding circumstances of a local community. They structured their criteria under seven 'SHTEFIE' factors. Unlike the Agrément SA performance criteria, Parr and Shaw's criteria (1999) consider social, health, economic, financial, institutional and environmental factors, in addition to technological factors.

The Guidelines for the identification of appropriate building construction methods in developing areas (Macleod, 1993), prepared for the Development Bank of South Africa (DBSA), provide a set of criteria for selecting appropriate technologies in projects developed in Southern Africa. These guidelines suggest that for a technology to be considered appropriate for a specific project, it has to:

- Be affordable, in terms of both "ability to pay" and "willingness to pay",
- Be acceptable to the client or end user,
- Answer to the needs of the community,
- Make optimal use of local resources,
- Be economically advantageous to the community, and
- Allow operation and maintenance by the community (Macleod, 1993: 1).

Unlike with Agrément SA's and Parr and Shaw's criteria (1999), the DBSA's criteria consider economic and social aspects.

#### **THE FRAMEWORK**

Gibberd (2003) proposes that an assessment framework have a hierarchical structure consisting of three key elements. These are a goal, factors/criteria and indicators. The main purpose of the framework for the Decision-Support Tool is to assist users in the selection of appropriate IBTs within the contexts of their social infrastructure projects. Table 5 illustrates the relationships between the factors, objectives, criteria and indicators. Each factor is divided into objectives and criteria. The objectives explain the importance of the factor in relation to the criteria. Each criterion is further divided into indicators.

Table 5 Summary of assessment framework

FACTOR	OBJECTIVE OF THE FACTOR	CRITERIA	INDICATORS
<b>SOCIAL</b>	To understand the needs and preferences of the community with regard to this technology	Community needs and preferences	Community accepts this IBT
<b>HEALTH</b>	To ensure that use of this technology will not negatively affect indoor air quality	Indoor air quality	Use of this IBT is appropriate to the brief No hazardous materials have been used in the production of this IBT
<b>TECHNOLOGICAL</b>	To ensure that skills development, training and provision of practical work experience opportunities are available for labourers in the community	Skills transfer	Systems are in place to ensure that opportunities for the transfer of IBT construction skills to the community will be available
	To ensure that this technology is compatible with existing building products and materials	Compatibility with existing products and materials	This IBT is compatible with existing building products and materials
	To ensure that this technology is durable and of good quality	Durability and quality	This IBT is structurally strong and stable
	To ensure that the design with this technology is compatible with the level of construction and maintenance expertise available locally	Ease of construction and maintenance	The local labour can construct with and maintain this IBT with ease
<b>ECONOMIC</b>	To ensure the growth and development of small, micro and medium sized enterprises (SMIMES) through the procurement of spare parts, materials or services related to this technology	Economic opportunity	This IBT is sourced from local SMIMES
	To ensure that this technology and its spare parts are available locally	Local sourcing	This IBT is available within a 400km radius of the site
	To ensure that labour is available locally to construct with and maintain this technology	Local labour	Spare parts for this IBT are available within a 400km radius of the site Labourers are available within the community
<b>FINANCIAL</b>	To ensure that the application of this technology matches the government's willingness to pay	Budget allocations for construction, management and operation	This IBT qualifies for a subsidy
	To ensure that the application of this technology matches the community's willingness to pay	The community's willingness to pay	The community is willing to pay for the operation and maintenance of this IBT
<b>INSTITUTIONAL</b>	To ensure that this technology uses the most efficient combination of public, private and community organisations to deliver these services	SABS compliance or Agrément certification	This IBT is Agrément certified
<b>ENVIRONMENTAL</b>	To minimize the use of resources and negative environmental impacts through careful reduction and management of wastes generated during the construction	Waste reduction and management	Construction waste from this IBT can be reduced through detailing and specifications

The assessment of each indicator is based on the information from the relevant Agrément SA certificate. Points are awarded as shown in Table 3.

**Table 3 Assessment Points**

Assessment	Points awarded
Yes/Satisfactory	1
≤400km from project site	1
No/Unsatisfactory	0
≥400km from project site	0

When all the indicators have been assessed, the points are summed up and an overall is obtained. Based on this score a recommendation and next action are presented, as shown in Table 4.

**Table 4 Scoring, recommendation and next action**

Score	Recommendation	Action
12	This IBT is appropriate for and may be used in this project (for example see Figure 6)	Contact the manufacturer for more information
≤11	Based on the comments highlighted below, this IBT is not appropriate for this project and should not be used (for example see Figure 7)	Consider using another IBT, then assess new IBT

**Application of the framework for the decision-support tool**

A number of assumptions are made when an assessment for an appropriate IBT is undertaken. Firstly it is assumed that the need for the project has been identified and secondly that the project goal and objectives have been defined. At this stage, the user may either know which IBT is proposed for the project, or which building occupancy is proposed for the project. Figure 3 shows the four steps adopted for using the framework for the Decision-Support Tool.

**i. Selecting the filter option:** Prior to assessing an IBT, the user has one of two options. If she knows which IBT will be used in a project, she selects “Option 1”. On the other

hand, if she only knows the project’s proposed building occupancy type, then she selects “Option 2”.

**ii. Project details and input data:** Regardless of which filter option is chosen, the user will then need to provide project details, including the name and location of the project.

After the project details have been provided, where the user knows which IBT to use (Option 1), she would first need to select an IBT from a longer unfiltered list. Following this, she would have two drop-down lists; one listing the building occupancies permitted for the selected IBT, the other listing the number of stories permitted when constructing with the selected IBT.





After the project details have been provided, where the user does not know which IBT to use (Option 2), she first need to select the building occupancy for the project. Following this, she would be able to make her selection from a shorter filtered list of IBTs specific to the selected building occupancy. Once the IBT has been selected, the user would have a drop-down list listing the number of stories permitted when constructing a building with the selected IBT.

**iii. Assessment, recommendations and next steps:** When the IBT has been selected, the building occupancy and number of stories determined and the location of the project identified, an assessment is generated. This presents some IBT-related information extracted from the relevant Agrément SA certificate (see Figure 4 and Figure 5).

## Conclusion

A framework for the Decision-Support Tool was presented in this chapter. This currently only lists IBTs within the Walling and building system

and Sanitation categories on the Agrément SA database. This framework is a useful start to helping local government officials become aware of and select appropriate IBTs in the development of future social infrastructure. There is potential for this framework to be expanded to include Agrément SA listed products in the remaining categories. Explorations to incorporate this into an existing tool, Decision Support Model for Innovative Building Technologies, should also be considered.

## Acknowledgements

This chapter has presented a framework for the Decision-Support Tool. The intention is that this be used to support the delivery of South African social infrastructure. The development of this framework was initiated and funded by the Department of Science and Technology. The framework is available from the Department of Science and Technology.

**Decision Support System to select Innovative Building Technologies (IBTs) in South African social infrastructure projects | v0.2**  
Option Two: Filtered IBT list (Filter: Building occupancy)

<b>Name of project</b>	Project ABC				
<b>Building occupancy filter</b>	Offices				
<b>Proposed IBT</b>	Alternative Steel Frame Building System				
<b>Building element</b>	Walling and building system				
<b>No. of stories allowed</b>	10				
<b>Location of IBT</b>	Private				
<b>Location of project</b>	Northern				
<b>Province</b>	Western Cape				
<b>Climate region</b>	Hot winter				
<b>Date of assessment</b>	24 February 2016				

<b>Recommendation</b>	
This IBT is appropriate for, and may be used in, this project	
<b>Next action</b>	
Contact the manufacturer for more information:	
T: Green Technologies (Pty) Ltd PO Box 72867 Lynwood Ridge, 7800 Telephone: 021 945 1221 Fax: 021 945 2281	

PARAMETER	CRITERIA	MEASUREMENT	AGREEMENT SA REQUIREMENT	COMMENT
<b>SCHEME</b>	Building occupancy	Building meets the occupancy allowed by manufacturer	Yes	This IBT meets the manufacturer's building occupancy requirements
	Number of stories	Building meets height restrictions allowed by manufacturer	Yes	This IBT meets the manufacturer's building height restrictions
<b>HEALTH</b>	Behaviour in fire	Fire resistance of a building with this IBT	Satisfactory	Walls are standard non-combustible type P10 with a fire resistance rating of 30 minutes
	Water penetration and drying time	Water penetration and drying time on a building with this IBT	Satisfactory	Alternative Steel Frame Building System buildings meet Agrément SA's criteria for resistance to water penetration and drying time (EN1090) South Africa
	Thermal performance	Thermal performance in a building with this IBT	Satisfactory	R-value = 0.23 m <sup>2</sup> /K/h. Maximum summer indoor temperatures in Alternative Steel Frame Building System buildings will be much less than those experienced at a standard load heating
<b>TECHNICAL</b>	Acoustic performance	Acoustic performance in a building with this IBT	Satisfactory	Agrément SA's performance criteria for sound attenuation between adjacent rooms and between adjacent dwellings have been met
	Structural performance	Structural performance in a building with this IBT	Satisfactory	All tested requirements of the certificate for this IBT are complied with
	Compatibility with conventional construction	This IBT is compatible with conventional construction	Yes	The Alternative Steel Frame Building System is a combination of innovative and conventional construction. A change to any one aspect could result in one or more of the other aspects no longer complying with Agrément SA's performance criteria. For these reasons, no change may be made to the Alternative Steel Frame Building System as described and listed and on the certificate for this IBT, unless such change is approved in writing by Agrément SA before it is implemented
<b>ECONOMIC</b>	Durability and quality	Durability of building using this IBT	Satisfactory	It is regular and adequate maintenance. The durability of Alternative Steel Frame Building System buildings will be similar to that of conventionally constructed buildings
	Local economy	This IBT is available within a 400km radius of the project site	322 km	Some parts for this IBT are available within a 400km radius of the project site
<b>REGULATORY</b>	SBES compliance or Agrément certification	Compliance of the agreement certificate for this IBT	Yes	This agreement certificate for this IBT is SBES advice

Figure 4 Screen-shot of a completed DSS assessment showing a recommendation to use the selected IBT

**Support System to select Innovative Building Technologies (IBTs) in South African social infrastructure projects | v0.2**  
 Filtered IBT list (Filter: Building occupancy)

<b>Project filter</b>	Project ABC
<b>Occupancy filter</b>	Offices
<b>IBT filter</b>	Alternative_Steel_Frame_Building_System Walling_and_building_systems
<b>IBTs allowed</b>	1
<b>IBT project</b>	Pretoria Kimberley
<b>Location</b>	Northern Cape And Interior
<b>Start date</b>	24 February 2015

CRITERIA	INDICATORS	ASSESSMENT	COMMENT
Building occupancy	Building meets the occupancy allowed by manufacturer	Yes	This IBT meets the manufacturer's building occupancy requirements
Number of storeys	Building meets height restrictions allowed by manufacturer	Yes	This IBT meets the manufacturer's building height restrictions
Behaviour in fire	Fire resistance of a building with this IBT	Satisfactory	Walls are classified non-combustible (type FRI) with a fire resistance rating of 30 m
Water penetration and rising damp	Water penetration and rising damp issues in a building with this IBT	Satisfactory	Alternative Steel Frame Building System buildings meet Agreement SA's criteria for water penetration and rising damp throughout South Africa
Thermal performance	Thermal performance in a building with this IBT	Satisfactory	R value = 0.939 m <sup>2</sup> K/W. Maximum summer indoor temperatures in Alternative Steel Building System dwellings with insulated ceilings will be much less than those expected in brick houses.
Acoustic performance	Acoustic performance in a building with this IBT	Satisfactory	Agreement SA's performance criteria for sound attenuation between adjacent rooms in residential dwellings have been met.
Structural performance	Structural performance in a building with this IBT	Satisfactory	Provided the requirements of the certificate for this IBT are complied with.
Compatibility with conventional construction	This IBT is compatible with conventional construction	Yes	The Alternative Steel Frame Building System is a combination of innovative and conventional construction. A change to any one aspect could result in one or more of the other aspects no longer complying with Agreement performance criteria. For these reasons, no changes may be made to the Alternative Building System as described and illustrated in the certificate for this IBT, unless approved in writing by Agreement SA before it is implemented.
Durability and quality	Durability of building using this IBT	Satisfactory	Given regular and adequate maintenance, the durability of Alternative Steel Frame System buildings will be similar to that of conventionally constructed buildings.
Local sourcing	This IBT is available within a 400km radius of the project site	330 km	Space parts for this IBT is more than 400km away from the project site
Space parts for this IBT	Space parts for this IBT are available within a 400km radius of the project site	330 km	Space parts for this IBT is more than 400km away from the project site
Validity of the Agreement certificate for this IBT	Yes	Yes	The Agreement certificate for this IBT is still active

**Recommendation**  
 Based on the comments highlighted below, this IBT is not appropriate for this project and will not be used.

**Next action**  
 Consider using another IBT, then assess new IBT

Figure 5 Screen-shot of a completed DSS assessment showing a recommendation not to use the selected IBT

## References

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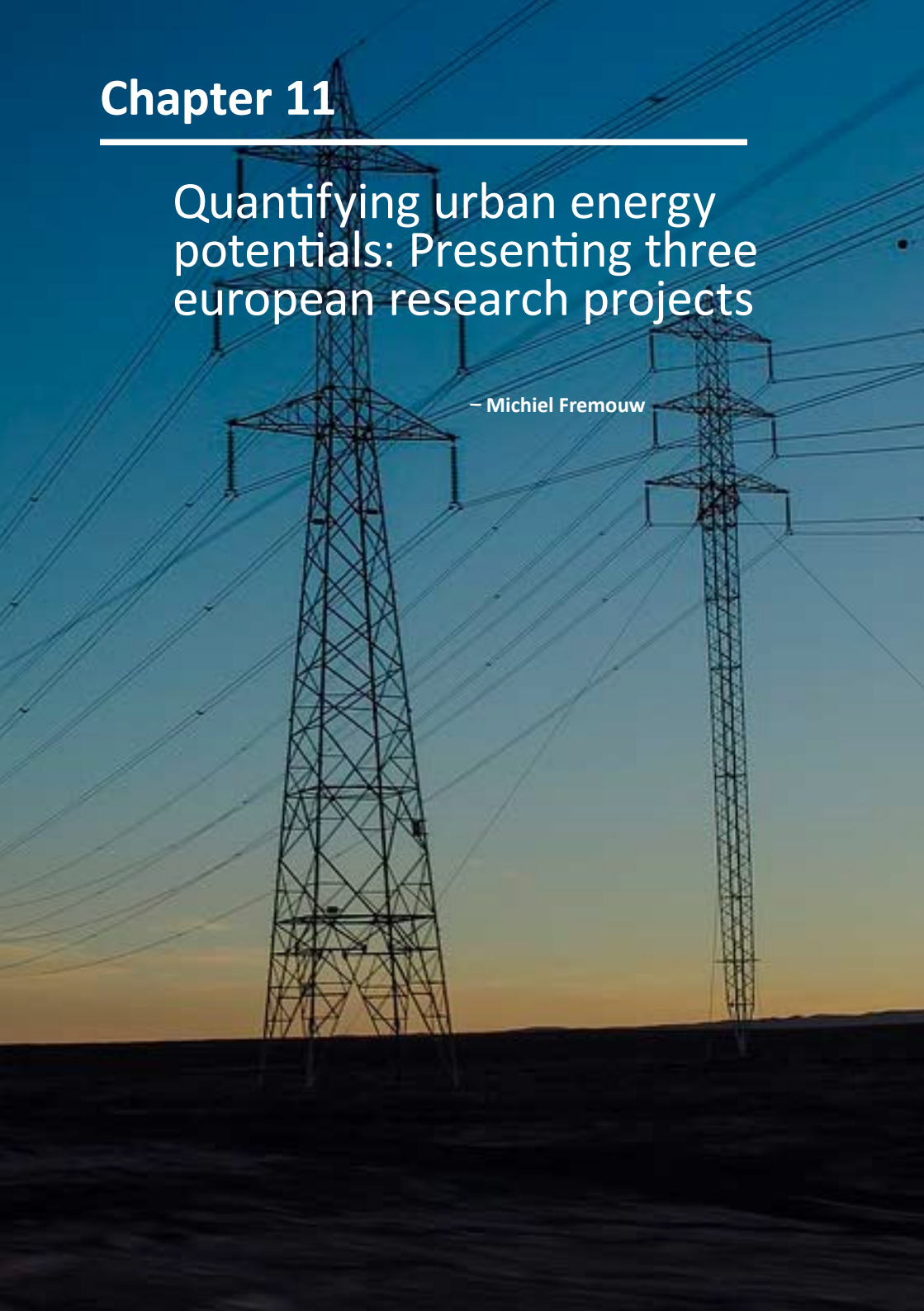
- Agrément SA, 2010. Assessments by Agrément South Africa. [online]. Available from: [http://www.agrement.co.za/uploads/cms/documents/Assessment\\_by\\_Agrement\\_South\\_Africa.pdf](http://www.agrement.co.za/uploads/cms/documents/Assessment_by_Agrement_South_Africa.pdf) [Accessed 3 Aug 2015].
- Agrément SA, 2014. Active Agrément Certificates. Active Certificates [online]. Available from: <http://www.agrement.co.za/certificates/active> [Accessed 3 Aug 2015].
- Brikké, F., Bredero, M., 2003. Linking Technology Choice with Operation and Maintenance in the Context of Community Water Supply and Sanitation: A Reference Document for Planners and Project Staff. World Health Organization and IRC Water and Sanitation Centre, Geneva.
- Burger, S., 2014. Innovative building technologies can aid delivery of social infrastructure.
- CSIR, 2005. Guidelines for Human Settlement Planning and Design (The Red Book). CSIR, Pretoria.
- Du Plessis, C., Duncker, L., 2000. Decision-making Framework for Technologies for Enhanced Environmental Management. CSIR.
- Ewing, B., Baker, E., 2009. Development of a Green Building Decision Support Tool: A Collaborative Process. *Decision Analysis* 6, 172–185. doi:10.1287/deca.1090.0146
- Foote, M.G., 1992. A framework for selection of DSS development methodology. Baylor University, United States.
- Jadid, M.N., Badrah, M.K., 2012. Decision Support System Approach for Construction Materials Selection, in: Proceedings of the 2012 Symposium on Simulation for Architecture and Urban Design, SimAUD '12. Society for Computer Simulation International, San Diego, CA, USA, p. 10:1-10:7.
- Keuter, M., 1977. National Building Regulations and Building Standards (as amended) [online]. Available from: [http://www.thedti.gov.za/business\\_regulation/acts/building\\_standards\\_act.pdf](http://www.thedti.gov.za/business_regulation/acts/building_standards_act.pdf) [Accessed 9 Sep 2014].
- Mema, V., n.d. Accelerating sustainable water services delivery phase two (ASWSD II): Limpopo and Mpumalanga - Technology selection criteria.
- Natividade-Jesus, E., Coutinho-Rodrigues, J., Antunes, C.H., 2007. A multicriteria decision support system for housing evaluation. *Decision Support Systems* 43, 779–790.
- Odhiambo, J., Wekesa, B., 2010. A framework for assessing building technologies for marginalised communities, in: *Human Settlements Review*. Pretoria, pp. 59–85.
- Palaniappan, M., Gleick, P.H., Change, E., 2008. A Review of Decision-Making Support Tools in the Water, Sanitation, and Hygiene Sector. Pacific Institute.
- Pan, Gibb, A.G., Dainty, A.R., 2008. A decision support matrix for build system selection in housing construction. *Journal for Housing Science and Its Applications* 32, 61–79.
- Parr, J., Shaw, R., 1999. Choosing an appropriate technology.
- Pearce, A., R., Hastak, M., Vanegas, J., A., n.d. A Decision Support System for Construction Materials Selection using Sustainability as a Criterion.

# Chapter 11

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## Quantifying urban energy potentials: Presenting three european research projects

– Michiel Fremouw



## Introduction

Energy is space. In the post fossil fuels world to come, this basic tenet dictates the need to investigate the relation between energy demand, renewable energy supply and their spatial characteristics. Living standards increase, the majority of the world's population now lives in urban areas, and both of these trends are expected to continue in the decades to come. In order to cope with the associated high energy demand, the high density of these areas means energy needs to be incorporated in urban planning practices.

The method of Energy Potential Mapping (EPM) (Broersma et al, 2013), developed at the chair of Climate Design & Sustainability at the TU Delft faculty of Architecture and the Built Environment, provides the means to spatially quantify sources and sinks in a unified way, thereby facilitating this integration.

## Energy Potential Mapping

At the basis of EPM is the relation between energy and space: as with urban energy demand itself, renewable sources can vary greatly in availability and concentration depending on the local spatial characteristics. Rules can however be defined that quantify these potentials.

A simple example is biomass (Error! Reference source not found.Figure 1): depending on soil, climate and agricultural practices, a certain yield per hectare can be expected in the form of tons of wood, or litres of biofuels. These can subsequently be converted into heat, motion

and/or electricity, and therefore an energetic potential can be tied to an area deemed suitable for production. In denser urban areas however, competing functions will result in more complex calculations and because of the limited availability of space in cities, multiple land use may be a prerequisite for some energy sources. For solar photovoltaic potential for example, the available roof space will be the basis, and for wind energy the distance to risk objects (houses, gas pipelines, highways). The end result however will be an amount of potentially harvestable energy per hectare per year.

For urban areas, this energy can be quantified in a small number of types (both demand and supply): electric, fuels and thermal (heating and cooling). Although conversion between these types is possible (and usually quantified as part of an EPM calculation), this unified way of presenting potentials makes it easier to connect demand and supply potentials. Although strictly speaking fuels and electricity are not considered 'useful energy', final conversion of these two energy carriers is not building related, and therefore they are included instead.

EPM supports the New Stepped Strategy (Dobbelsteen et al, 2012) of reducing demand, then considering exchanging, cascading and storing opportunities and finally generating the remaining required supply sustainably. The end result will be a series of demand categories and supply potentials, which can then be used to formulate an energy based plan.

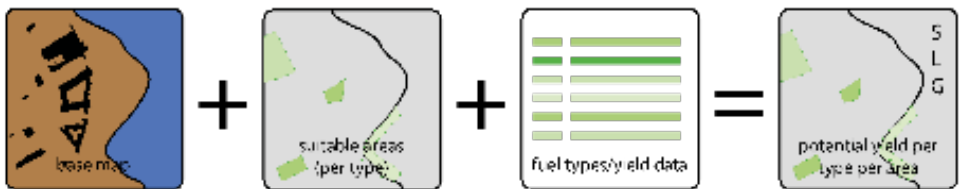


Figure 1 Basic EPM calculation for biomass (Fremouw, 2012)

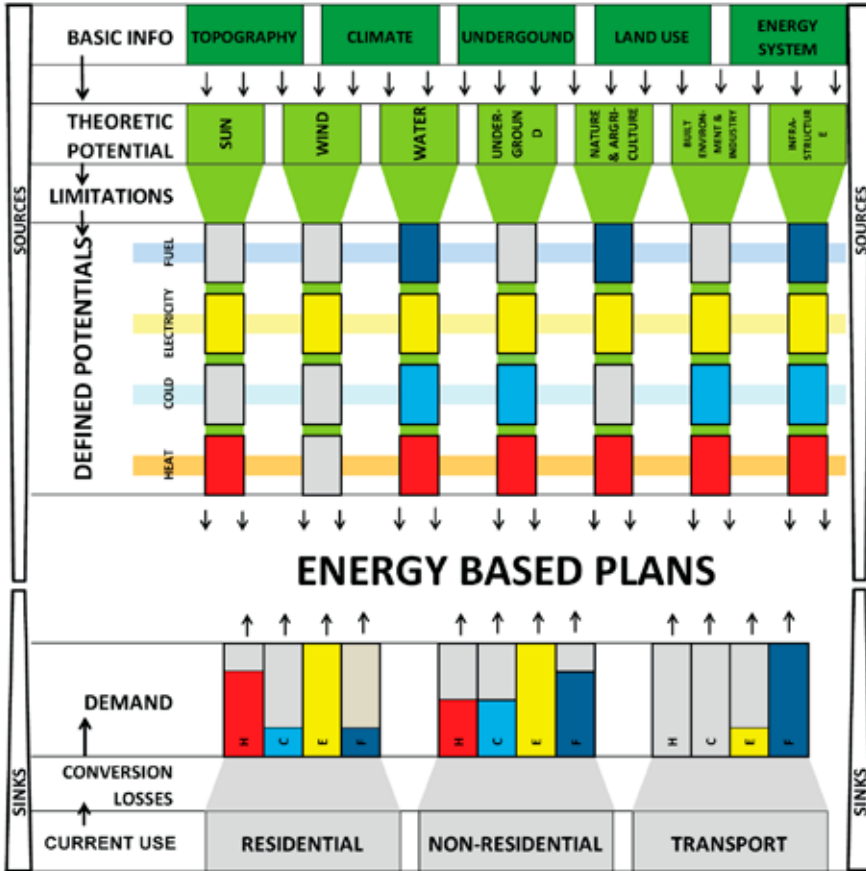


Figure 2 EPM representation (Broersma et al, 2013)

Figure 3 is a schematic representation of the EPM principle. As the horizontal orientation in the figure suggests, the intent is to make demand and supply meet in the middle, in order to facilitate urban energy planning. On the left hand side, current use (usually related to energy carriers like natural gas) is derived to calculate useful energy demand (Madureira, 2014), in order to remove technology specific conversion losses. On the right hand side, spatial and technology characteristics are

applied to arrive at defined supply potentials. Both demand and supply are divided by the energy forms most common in an urban environment: Heating, Cooling, Electricity and Fuels.

An example of deriving useful demand from final consumption figures is natural gas, frequently collected remotely and transported through a large network to the end user. 'Final consumption' here does not represent the required useful energy for indoor heating, as this

is measured at the front door and conversion to heat in a boiler incurs a subsequent energy loss. Furthermore, as a percentage will be related to cooking, this needs to be subtracted from the initial demand figure, in order to arrive at the (potentially low temperature) space heating component of gas consumption. For this cooking component, a high exergy source will still be required (for example biogas or electricity), however this will be a small fraction and therefore more easily manageable in an otherwise predominantly lower temperature system.

For heating purposes, a potential replacement on the (renewable) supply side

would be using a ground based heat exchanger and heat pump, which is a significantly different process and therefore has different conversion losses for the same useful demand. As mentioned, in this regard the term 'final energy demand' relates to an energy carrier reaching the consumer's front door, and therefore may not represent the right consumption and production figures.

### Urban Energy Atlas

The collected geospatial data can subsequently presented as a series of maps, either as separate documents using the same projection (portrayed in Figure 34), or in a combined

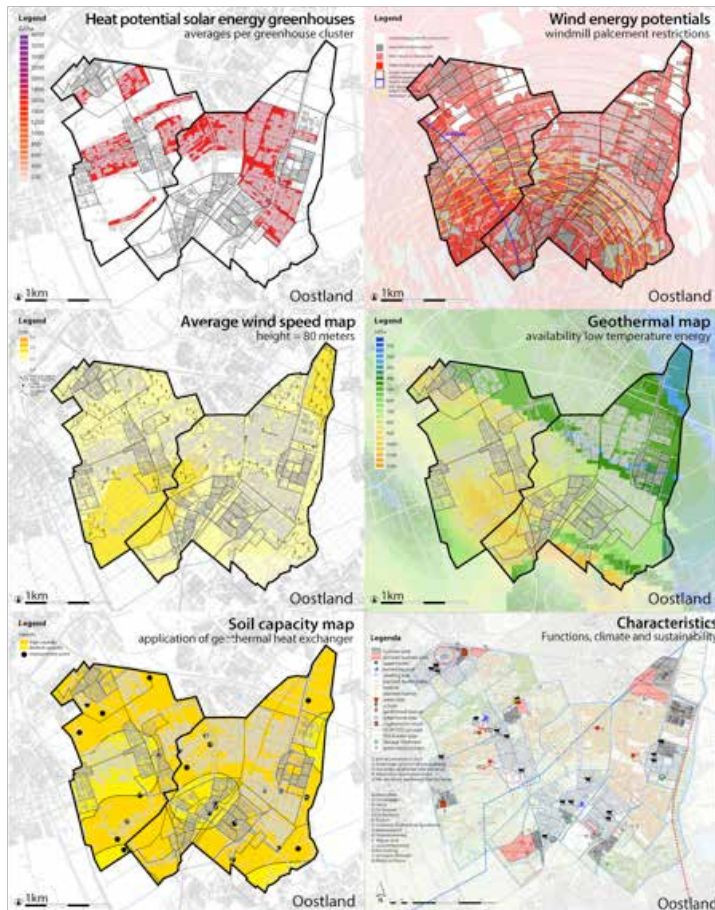


Figure 3 Selection of energy potentials of the Oostland area (Broersma et al, 2013)

interface. A common occurrence of this is in so-called Decision Support Tools (DSTs) or Decision Support Systems (DSS'es), which usually provide a map interface comparable to google maps, in which individual layers can be turned on and off. Visualization can be adjusted to project multiple layers of information in a single view. The ultimate goal is to provide a catalogue of energy potentials that can be projected on top of present and future energy demand, in order to shape the aforementioned energy based plans.

Visualisation is not limited to two dimensions. An example is the 3D heat map of Rotterdam (NL), as shown in Figure 45. Here, demand (GJ, for the visualisation normalised by area to negate neighbourhood size differences) is represented by a series of hollow cores (following the contours of neighbourhoods), which are filled by local heat potentials. Although based on a limited set of potentials, the discrepancy between demand in the high rise dominated centre and the more balanced (and sometimes surplus capable) periphery

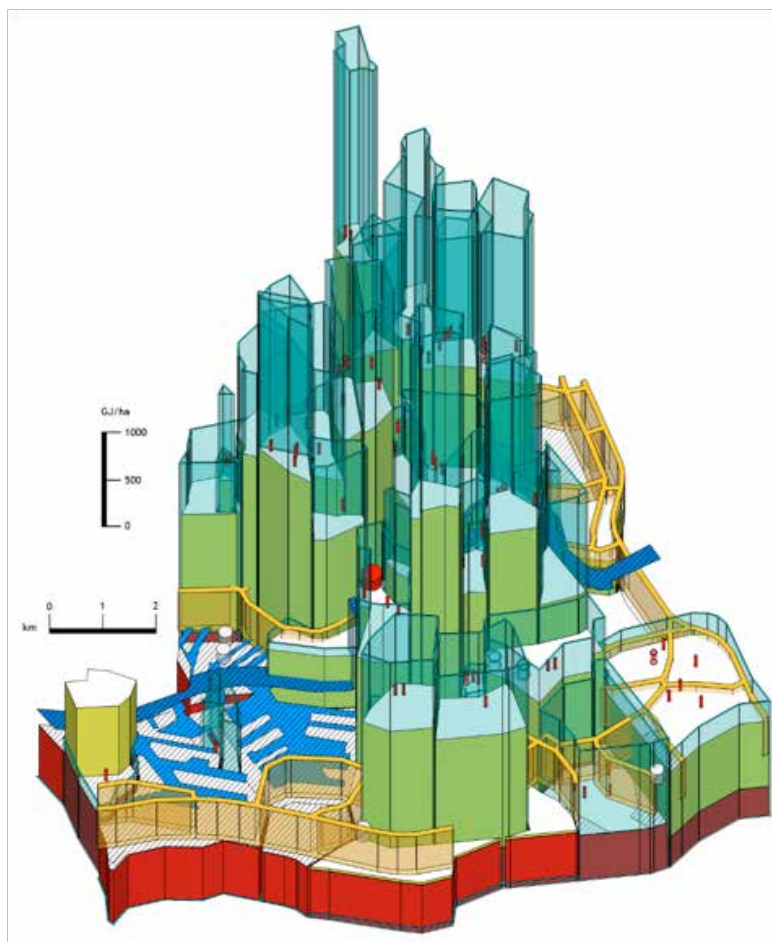


Figure 4: 3D heat map of Rotterdam (Broersma et al, 2011)



is clear, demonstrating the need for a District Heating (DH) network.

### Applications

Since its inception over a decade ago, the EPM method has been used in many different projects, covering a wide range of scales from individual neighbourhoods to cities, regions and countries, and providing an ever increasing level of detail, source data permitting. Three currently running research projects are highlighted here, to show the various ways in which EPM principles are applied to real cities.

### CELSIUS

The premise of the CELSIUS project ([www.celsiuscity.eu](http://www.celsiuscity.eu), 2013-2018, part of the European FP7 programme) is that urban heating and cooling demand in European cities, at present still overwhelmingly supplied using fossil fuels, can easily be covered by residual and renewable sources, as well as more efficiently operating District Heating and Cooling (DHC) networks (Figure 6).

The project revolves around so-called demonstrators, innovative technologies at a high Technology Readiness Level (TRL) that are built and monitored in one of the five partner cities (Gothenburg (SE), Rotterdam (NL), London (UK), Cologne (DE) and Genoa

(IT)), and have replication potential. CELSIUS aims to spread its knowledge and experience by actively recruiting so-called replication cities (currently numbering 65), who have expressed interest in adopting CELSIUS demonstrators and developing their HC networks using CELSIUS knowledge.

In CELSIUS, the EPM method is used to determine both suitability for and quantifiable potential in so-called replication cities, by defining spatial calculation methods for these demonstrators. An example is the Rotterdam river water cooling demonstrator, where the EU water framework directive was applied to define upper thermal exhaust limits for lakes, rivers and seas, thereby making it possible to quantify cooling potential in suitable cities (Fremouw et al., 2015).

In order to support demand (and refurbishment) quantification, pathways were mapped (Figure 56) for various types of energy demand maps, taking into consideration data availability, detail levels, privacy concerns and the advantages (and disadvantages) of different types of output.

The PLANHEAT project (discussed in section 4.3) will address these issues in greater detail, as the toolset it develops requires certain types of base data in order to operate.

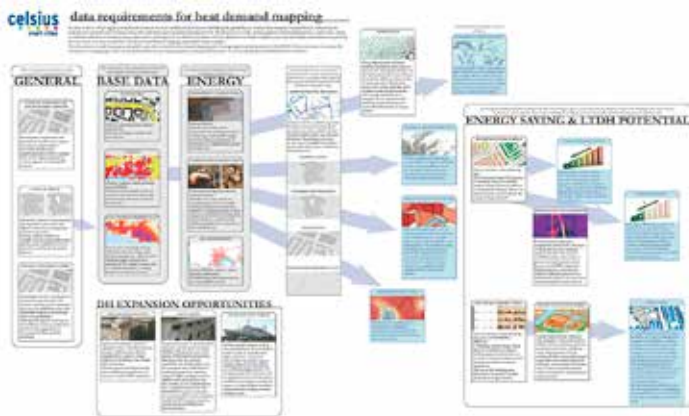


Figure 5 Mapping heat demand (Fremouw, 2015)

### City-zen

The aim of the City-zen project ([www.cityzen-smartcity.eu](http://www.cityzen-smartcity.eu), 2014-2019, also part of the FP7 programme) is to support and accelerate sustainability targets in urban areas, with a focus on integrating building retrofit measures, the introduction of smart grids and renewables based heating and cooling. As the name suggests, involving citizens and starting at the neighbourhood scale (rather than top-down) play an important role.

Similar to the CELSIUS project, City-zen combines the development of new knowledge and tools with live test beds, in the form of participating cities and a dozen technological demonstrators with a high technology readiness level. Examples of demonstrators are a blood bank in Amsterdam which recently started using a water purification supply line to provide its cooling, and Grenoble’s Vivacité, an experimental platform for collaborative energy data management.

Lead cities Amsterdam (NL) and Grenoble (FR) have ambitious sustainability targets, but owing to the ever changing priorities of the stakeholders involved (for example national and local government, citizens and businesses), the path towards these is not always certain. Furthermore, regulatory, financial and social barriers may need to be overcome in order to accomplish a larger share of the technical potential that’s available in a city.

Figure 7 shows a simplified energy potential pyramid, where subsequent limitations result in a much smaller share of the physical potential is actually built and operational. Although using 100% of physical potential will be impossible for various reasons, the top layer in this figure can none the less be significantly wider.

The City-zen methodology (Dobbelsteen et al., 2014) aims to connect the long term sustainability targets (“visions”) of cities with their present state and (energy) potentials, taking into account the long term resilience of possible solutions and emerging synergies in order to arrive at an economically viable, fully sustainable future urban energy system: the Energy Master Plan (EMP).

Figure 78 represents the overall structure of the EMP. Here, the EPM method and its resulting Urban Energy Atlas provide the quantified starting point (the “present” on the left) from which a roadmap can be built towards this vision. Owing to the long period of time covered between the present and the vision (for example 2050) and its accompanying uncertainties (for example resulting from global external factors represented here by “scenarios”), the roadmap cannot provide detailed blueprints. Rather, it deals with strategic choices and areas of interest, for example the level of retrofitting versus available residual / renewable heating and cooling (HC) sources, their temperatures and availabilities, or perhaps a stronger

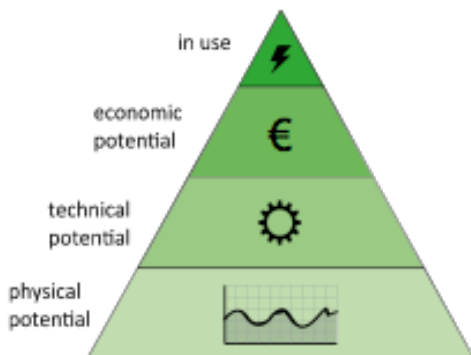


Figure 6 From theoretical potential to application (Fremouw, 2012)

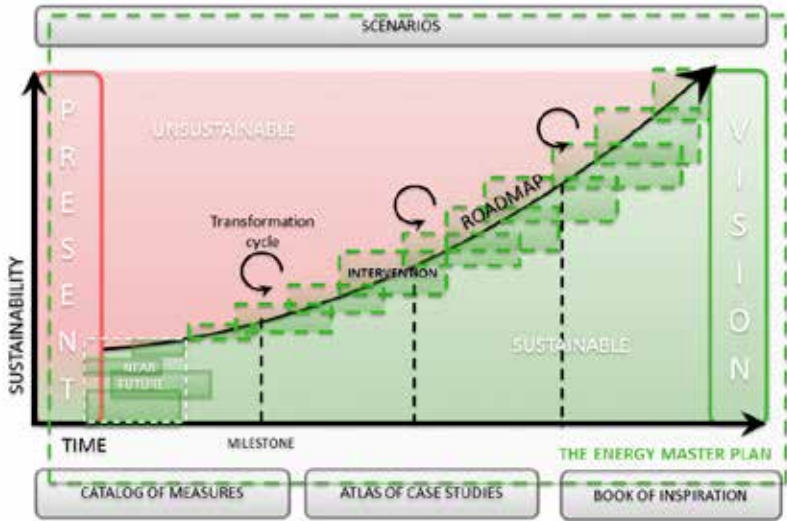


Figure 7 The City-zen methodology (Broersma & Fremouw, 2015)

focus on wind energy and electrification. As time progresses, more detailed plans can be made for specific areas that fit these strategic choices, and at each milestone, progress will be evaluated, possibly followed by a readjustment of plans.

A supporting product of the City-zen project will be the Catalog of Measures, which aims to record common barriers encountered for various energy measures and provide the means to level them, called opportunities here. These frequently address regulatory, financial and social issues simultaneously in order to achieve both economic viability and social acceptability.

The knowledge and tools developed in the City-zen project are tested in ten so-called roadshows, where, after preparation, a group of City-zen experts visits a city and helps local stakeholders shape a roadmap in a week long workshop. So far, four roadshows have been organized in Belfast (IE), Dubrovnik (HR), Izmir (TR) and Menorca (ES). The next roadshow will be in partner city Amsterdam (NL), in October 2017.

## PLANHEAT

The recently started and Horizon 2020 funded PLANHEAT project ([www.planheat.eu](http://www.planheat.eu), 2016–2019) aims to develop open source renewable Heating and Cooling (HC) mapping, planning and simulation tools at the urban scale (Figure 9). Partners from eight countries across Europe (including validation cities Antwerp (BE), Velika Gorica (HR) and Lecce (IT)) work on PLANHEAT, which focuses not just on the toolset itself, but also on solving data acquisition and management issues on the input and output sides. Even within the 28 European Union member states (EU28), the availability of source data varies significantly, and although certain base data will always be required (but usually available from a public EU wide or national database), methods and procedures are being developed to provide (sometimes lower resolution) alternative data and identify analogs, as well as both simple and complex calculation methods.

The energy potential mapping module provides calculation methods for HC demand, demand reduction and supply. When

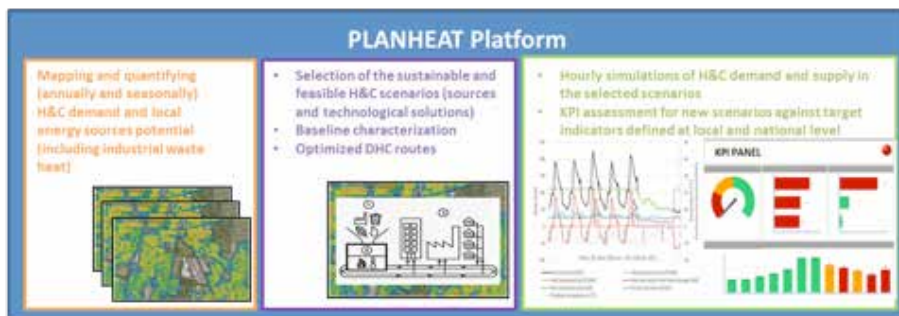


Figure 8 PLANHEAT platform structure

combined with the network maps that the planning and simulation modules require, this provides the layers for an Urban Heating and Cooling Atlas. The mapping module will also provide the input for the planning and simulation modules, which allow the shaping and validating of local HC plans. Special focus is placed on the Urban Heat Island (UHI) effect, and its consequences for present and future cooling demand. Satellite data will be used to assess local UHI consequences.

The end result will be an open source, interoperable and freely downloadable mapping, planning and simulation toolset for urban HC planning. During the project, training modules will also be developed and webinars organized to get new users started quickly. The first webinar is planned for September 2017, introducing the project and identifying data acquisition strategies.

## Outlook

In the past decade, great strides have been made in the field of Energy Potential Mapping,

starting with simple maps of opportunities ('kansenskaarten') (Dobbelsteen & Stremke 2009), and at present able to use building detail level GIS data to forecast future energy demand and calculate supply potentials for the urban and regional scale. Methods to further integrate temporal components (demand and supply curves), multiple temperature levels (see also Broersma & Fremouw, 2013) as well as strategies to deal with varying data availability and detail level and local circumstances affecting (or accelerating) transition, are currently under development.

The brief period in human history of a strong spatial separation between demand and supply that the fossil fuel age forms, will undoubtedly come to an end in the 21st century. Our continuing desire for and move toward higher levels of urbanization, and the relation between energy and space, therefore mean that for these dense urban areas, thorough energy based planning will be of paramount importance.

## References

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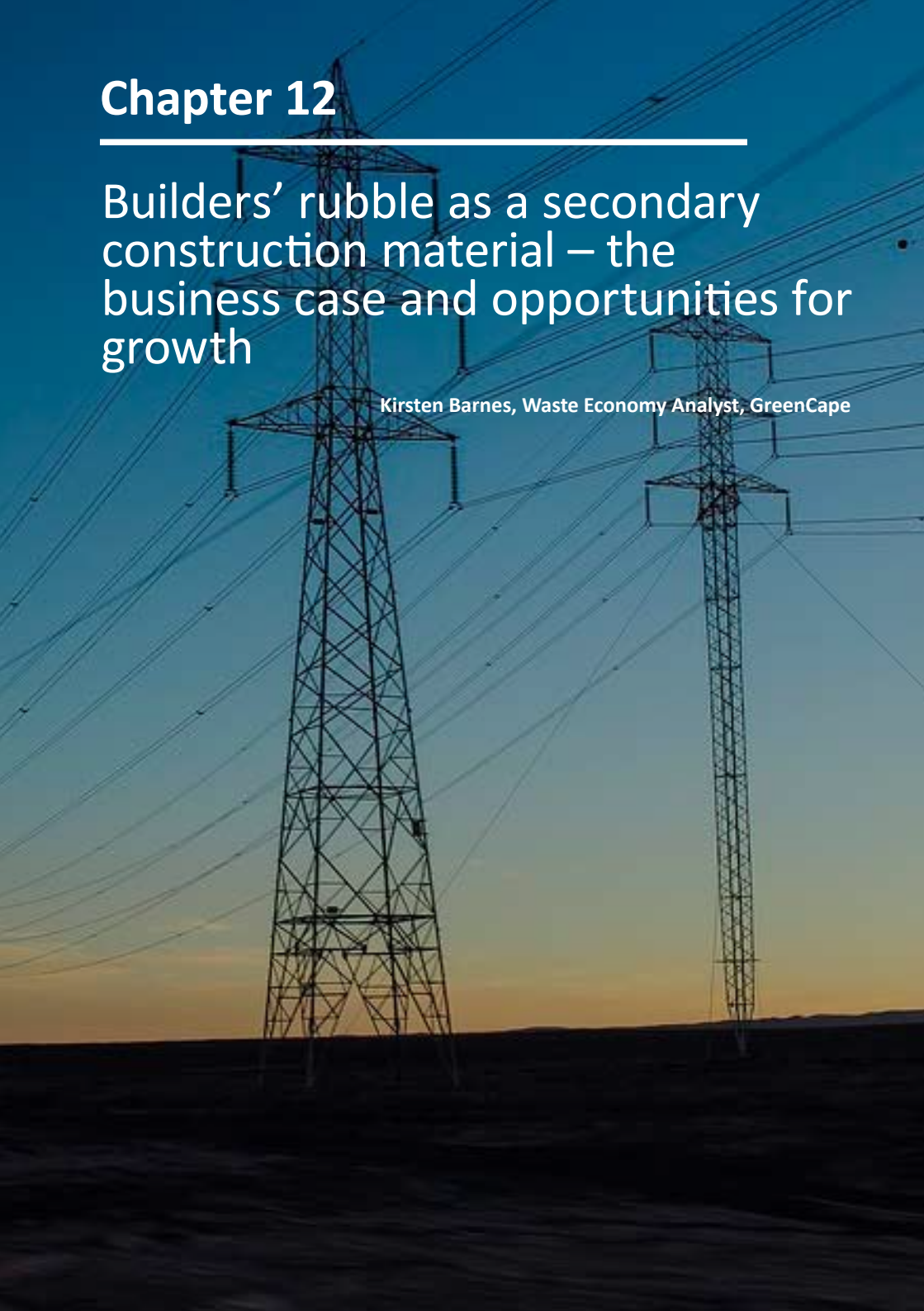
- Broersma, S., Fremouw, M.A. & Dobbelsteen, A.A.J.F. van den (2011) Heat Mapping the Netherlands, laying the foundations for energy-based planning, Helsinki, SB11
- Broersma, S., Fremouw, M.A. & Dobbelsteen, A.A.J.F. van den (2013) Energiepotentiëstudie Oostland - Met een regionale energie-analyse naar lokale duurzame ingrepen, Delft: Delft University of Technology.
- Broersma, S., Fremouw, M.A. & Dobbelsteen, A.A.J.F. van den, (2013) Energy Potential Mapping: Visualising energy characteristics for the exergetic optimisation of the built environment. Entropy, Issue 15, pp. 490-506
- Broersma, S., Fremouw, M.A., (2015) The City-zen approach for urban energy master plans, Pretoria, SASBE2015
- Dobbelsteen, A.A.J.F. van den & Stremke, S., (2009) Energiepotenties Groningen – basisrapport
- Dobbelsteen, A.A.J.F. van den, Keeffe, G. & Tillie, N.M.J.D. (2012) Cities ready for energy crises - building urban energy resilience, SASBE2012
- Dobbelsteen, A.J.J.F. van den, Tillie, N.M.J.D., Broersma, S. & Fremouw, M.A. (2014) The Energy Master Plan: Transition to self-sufficient city regions by means of an approach to local energy potentials, Ahmedabad, PLEA2014
- Fremouw, M.A. (2012) MUSIC: GIS based EPM and residual heat potential
- Fremouw, M.A. (2015) CELSIUS: Data requirements for heat demand mapping
- Fremouw, M.A. (ed.) (2015) CELSIUS: D5.7 Concepts for energy efficient and sustainable energy production
- Madureira, N.L. (2014) Key concepts in energy, Heidelberg, Springer, p.10

# Chapter 12

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## Builders' rubble as a secondary construction material – the business case and opportunities for growth

Kirsten Barnes, Waste Economy Analyst, GreenCape



## Abstract

The built environment is dependent on material flows to maintain, renew and develop buildings and other infrastructure. In this era of increasing resource scarcities and rising energy costs, key considerations for any city are the development of a resilient system which conserves, cycles and maintains its resources at the highest material value.

Growth in the Western Cape's construction industry is constrained by the increasing cost of virgin mineral building materials (cement, brick, concrete components etc.) (Windapo & Cattell, 2013). As a result, some construction companies now recognise existing building and infrastructure stock as 'in situ' mineral construction materials, not 'wastes' to be demolished and extracted from the built environment for disposal.

In order to design for resilience, the volumes of builders' rubble available, the quality of the material and the business case in the current economic climate are important data to consider.

This paper presents the status of the market for builders' rubble in the City of Cape Town, and therefore provides insights into resilience in terms of materials for Cape Town, and the potential nationally.

## Introduction

Builders' rubble is usually landfilled in South Africa, in spite of its potential for re-use. The result is that material flows of builders' rubble within the economy is unreasonable in an industry facing substantial economic pressure.

Traditional material flows in the construction industry have excavated material as well as that produced by demolition transported to landfill at some distance away, while virgin construction materials are sourced from quarries and mines at some distance from the construction site. In a glaring example of unreasonable material flows, during construction of a building in Philippi excavated sand was due to be carted away to landfill, while 'virgin' sand mined just a few kilometres away was to be delivered to the

site. In this case, the architect and consulting engineer questioned the unreasonable material flow, and the excavated sand was re-used on-site. Although excavated materials and demolition rubble may need some treatment and processing before re-use, a consideration of resource flows and costs will often favour the secondary material.

In terms of material value, we should consider that aggregate is quarried and processed on a site usually some distances from areas being developed, therefore consider the logistics costs along with the processing costs, especially in the light of rising energy prices. The aggregate will then be used in a structure or a road. At the structure or road's end of life, the aggregate will be extracted within the matrix of the building materials, and transported to landfill, where there will be costs involved in stockpiling or landfilling the material.

If all the resources – the time, the costs, the energy – across the full life of the material is taken into account, we can attribute an intrinsic value to the material (Fig. 1). It must be noted, that generally stone aggregate and even concrete retain most if not all of the properties which resulted in its selection as a building material in the first place.



Figure 1 Clean builders' rubble as a valuable resource

Secondary construction materials do not come neatly packaged and are only rarely accurately streamed within the waste generated. The material comes with a 'history' and the value chain up to the point of processing and reuse as a construction material is a key consideration indicating the quality of the secondary construction material. Furthermore, to ensure consistency in the quality of material produced, best practice in handling and processing must be widely applied.

In spite of these factors, virgin construction materials may underperform relative to well-handled secondary materials. This may be due to the natural composition of the virgin construction materials, for example some Cape quarries no longer produce sub-base material for roads due to the high clay content, as well as secondary properties of the rubble itself, such as self-cementation due to unhydrated cement within the concrete resulting in unexpected strength development and better compaction achieved.

**Value chain – builders’ rubble**

In order to acknowledge the value in builders’ rubble, the material is termed RCA (recovered

concrete aggregate), RCM (recovered concrete and masonry) or RMA (recovered masonry aggregate). Differentiation in these terms is necessary due to the very different quality and application of recovered aggregate.

Figure 2 illustrates the return of recovered aggregates into the economy, by accessing the waste cycle of construction materials, and either processing for inclusion in the same process (e.g. reject pre-cast concrete products being crushed and returned into the same process they resulted from), or capturing the 'waste' products for processing and application in a different process.

**Is there a business case in the South African context?**

The uptake of builders’ rubble as a secondary construction materials is more widely practised in developed countries. This uptake is largely driven by; high landfill fees, legislation that encourages waste diversion and the availability of virgin materials being limited due to high input costs for the excavation and transportation of the material and/or an actual scarcity of the material.

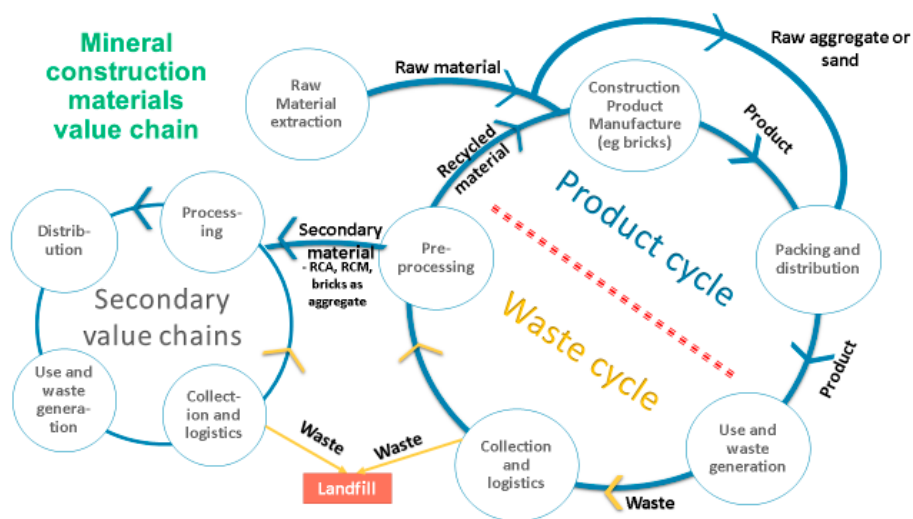


Figure 2 Builders’ rubble value chain - extracting maximum value from the resource



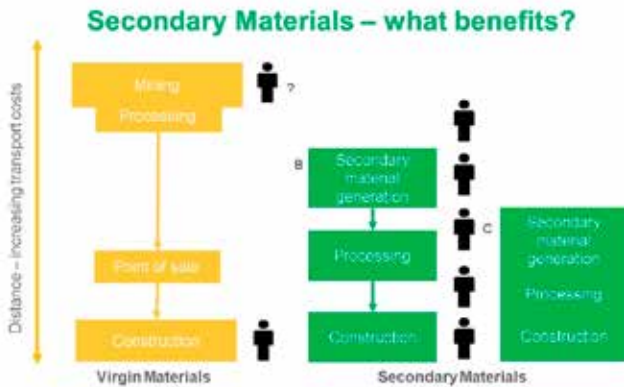


Figure 3 Logistics as the key factor in the recovered aggregate business case the main factor responsible for

In the South African context, landfill disposal fees are very low, which results in alternative waste treatments being generally more expensive than landfilling (Department of Science and Technology, 2014). In many areas clean builders' rubble does not attract any disposal fees, with the goal to encourage the disposal of builders' rubble at landfills or dropoff sites rather than through illegal dumping. Given the financial struggles of many households in the country, it is unlikely that we will see a uniformly applied increase in landfill fees that could stimulate a secondary materials economy.

Furthermore, there is currently no South African legislation incentivising the diversion of construction and demolition waste, including clean recovered aggregate, from landfill. Although the Waste Act does hold generators responsible for their waste, and the waste hierarchy is stipulated for implementation, there are currently no mechanisms of enforcement.

Unlike the Netherlands which has no natural aggregate available within its borders, development in most regions across South Africa is not limited by the availability of mineral resources needed for construction, e.g. the Western Cape has over 100 years of aggregate available.

In spite of the absence of these drivers, a growing market in recovered construction

limiting company growth. This was highlighted by Windapo and Cattel (2013) who surveyed a diversity of construction stakeholders in the Western Cape.

The key to the business case in all regions, is that it is largely driven by a local market. Figure 3 illustrates the advantage inherent in secondary construction material markets. Virgin aggregates are generally produced at some distance from the point of application, while secondary aggregate is generated within developing areas with a high aggregate demand. Coupled with the rising transport costs including increases in labour and fuel costs, the business case for secondary aggregate continues to strengthen, such that any handling or processing costs to produce the secondary construction material, are overshot by the transport costs for virgin aggregate. As a result secondary construction materials may be sold at a lower price than virgin materials, and still realise a profit for the crushing or the construction company reusing its own materials.

### **The market for recovered aggregate in the City of Cape Town – supply and demand**

The recovered aggregate market in the City of Cape Town (CCT) is showing robust growth.

There is scope for market expansion as a result of drivers such as rising virgin material costs, increasing transport costs, and limited landfill airspace available resulting in interventions by local governments to divert waste from landfill.

Data on clean builders' rubble stockpiled at the three City of Cape Town landfills is presented in Figures 4a and b, while the crushed rubble volumes have been calculated from a survey of 9 crushers in Cape Town. The crushing capacity in Figures 4a and b is based

on the capacity available across all the crushing companies, for an ideal volume processed per working day over a year.

In 2016, 840 000 m<sup>3</sup> builders' rubble was landfilled/stockpiled at landfill in the City, which is ~40% higher than the baseline year of 2015. At least 25% of this material has been assessed as suitable for sub-base in roads. Therefore, an extra 17 500 m<sup>3</sup> of high quality material with a value of about R2.3 million is available to the market per month in the CCT.

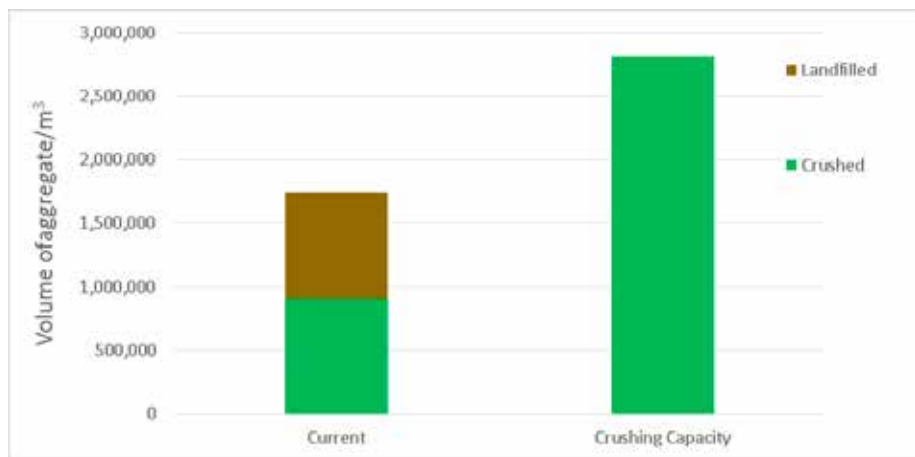
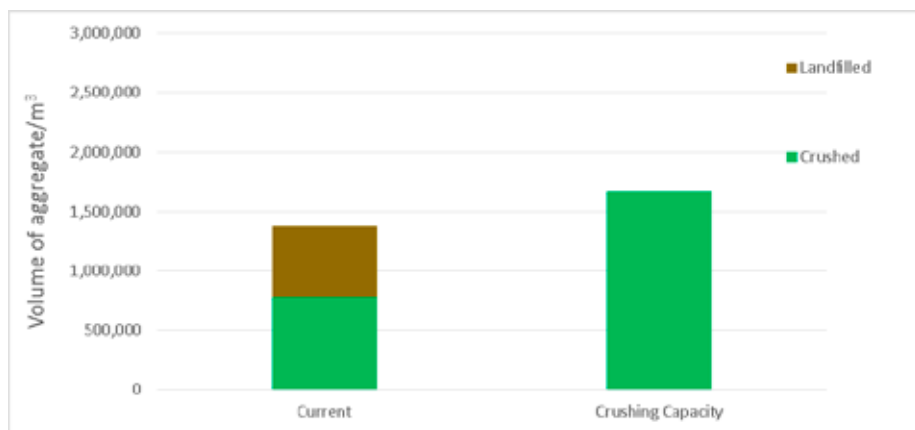


Figure 4a and b Status of the Crushing Industry in Cape Town 2015-2016

In 2015, 57% of clean builders' rubble was processed and applied, while this decreased to 44% in 2016. The decrease can be attributed to some companies focussing on their core businesses rather than rubble recycling, in two cases due to difficulties in waste management licensing and the better enforcement of the Waste Act in the City. A further two companies were constrained in their activities due to stringent waste management licensing requirements. Although the actual volume processed declined, the crushing capacity available from the same nine companies increased by 44% by September 2017 to 2.4 million m<sup>3</sup> of capacity in the City. The decline in the proportion processed may also be attributed to an increased volume of clean rubble stockpiled at landfill, and increase of 42% from the 2015 baseline year.

This increase in clean rubble at landfill may also reflect improved segregation of building and demolition waste, such that clean loads may be taken to landfill for no charge. With the City of Cape Town soon to re-establish crushing operations at all three landfills through a tender process, this material stockpiled at landfill will be available to the private sector in the near future.

### **Market developments for recovered aggregates**

A number of initiatives are driving perception change with regard to recovered aggregate as well as enabling growth in the industry through a range of interventions.

### **Establishing crushing companies**

Under the National Environmental Management: Waste Act (2008), the listed activities updated in 2013 included a waste licence trigger of an operational area greater than 1000 m<sup>2</sup> for all recycling activities. The vast majority of crushers exceed this operational area as strictly the limit includes incoming and outgoing stockpiles.

Norms and standards for the sorting, shredding, grinding, crushing, screening or baling of

general waste will soon be published, and will supercede the listed activities for these operations. Consequently, crushers will no longer require a national waste licence, but will be required to register with the provincial department of environmental affairs if an operational area of 100 m<sup>2</sup> is exceeded. The norms and standards will include guidelines for site establishment and operation as well as auditing and reporting to the department.

### **Access to municipal feedstock**

Many municipalities across South Africa are under increasing pressure to divert waste from landfill, as landfill airspace becomes critical. Establishing new landfills is costly and onerous in terms of environmental and social impact assessments, and will generally attract a significant cost increase over current solid waste tariffs and fees.

As a result, municipalities from Knysna to Stellenbosch, Tshwane to Msunduze, Cape Town to Mossel Bay are currently considering or are already in process of diverting waste to crushers at landfill or nearby sites. A formal tender has been adjudicated in the City of Cape Town to appoint contractors at all three landfills in the City, and Stellenbosch has published a request for quote for crushing at the Devon Valley landfill. Ekurhuleni Municipality has instituted a pilot project at the Simmer and Jack Landfill assisted by the National Cleaner Production Centre. Pilot projects are proving useful to demonstrate the business case for such operations, and more landfill crushing contracts across the country are expected.

### **Quality governance for crushing companies and their products**

The consistency and quality of product is perceived to be questionable by potential end users from both the public and private sectors. Given the demonstrated volume of recovered aggregate entering the construction industry, four major construction industry bodies have demonstrated their interest in engaging further on quality governance of recovered aggregates.

The Aggregate and Sand Producers' Association of South Africa (ASPASA) has admitted its first member crushing recovered aggregate, and has developed a quality guidance system that is application to primary and secondary aggregate. GreenCape is facilitating further talks towards a quality assurance system that will satisfy the construction industry.

### **Accessing the opportunity in roads**

Based on international experience, the biggest opportunities in the application of recycled builders' rubble lie in road building. For example in Japan and the Netherlands with 90-95% diversion rates of construction and demolition waste from landfill, about 80% of the diverted material is used in the construction of roads. There are therefore opportunities both on the supply side for the crushing industry, as well as on the demand side in road construction.

Material of sufficient quality for road construction in the private sector is already available, with construction companies citing lack of specifications and reluctance on the part of municipal and provincial government to include secondary materials, as the main stumbling blocks for the industry.

The Road Pavement Forum, a national biannual gathering of key road industry stakeholders has instituted a RecMat committee to develop guidelines for the application of recovered aggregate in roads. The committee's inception was facilitated by GreenCape, and members include SANRAL, Transport for Cape Town, University of Stellenbosch – Pavement

Engineering, Department of Transport and Public Works, ASPASA, Martin and East, BVI Consulting Engineers, DEA&DP as well as City of Cape Town – Solid Waste. The document includes a case study on the learnings from re-application of concrete road building material in the expansion of the N2 to three lanes in the vicinity of Cape Town International Airport. Certain chapters are currently in review, and it is hoped that there will be a full draft by March 2018.

### **Conclusion**

The developments presented in the recovered aggregate market are expected to accelerate over the next 2-5 years, given that current drivers of energy costs due to processing and transport continue to strengthen. The economic constraints on construction in South Africa have resulted in an increasingly competitive industry with limited profit margins which will further incentivise the use of recovered aggregates.

Furthermore, all levels of government have highlighted construction and demolition waste, of which builders' rubble forms the largest proportion, as a focus waste stream to be beneficiated and diverted from landfill. A recent strategy session on waste in South Africa convened by the national Department of Environmental Affairs, similarly selected construction and demolition waste as a key waste stream for development. It is expected that regulations and other financial instruments will be used to effect this change.

## References

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- 
- City of Cape Town, Solid Waste Department 2015-2016. Builders' rubble disposed of at landfill in the CCT, January 2015 – December 2016.
- Department of Science and Technology 2014. A National Waste R&D and Innovation Roadmap for South Africa: Phase 2 Waste RDI Roadmap. The economic benefits of moving up the waste management hierarchy in South Africa: The value of resources lost through landfilling. Department of Science and Technology: Pretoria.
- Windapo, Abimbola O. and Cattell, Keith 2013. The South African construction industry: Perceptions of key challenges facing its performance, development and growth. *Journal of Construction in Developing Countries*, 18 (2), pp. 65-79.

# African Horizon Technologies - Overview

African Horizon Technologies (AHT) offer a complete range of water filtration and waste water treatment solutions for all industries. AHT through their product range, is your source for innovative water treatment systems and technologies.

African Horizon Technology is a supplier of advanced, technology-based products that offer solutions to the mining-, oil & gas-, manufacturing-, food-industry. A South African-based equipment supply company, with a global reach, that supplies filtration, separation, bio remediation products, and purification technologies. This technology is vital to various industries and to environmental management. We produce our products locally which allows for better turnaround time, service and tailor-made solutions.

The decades of experience in environmental engineering and filtration engineered solutions, African Horizon Technologies provides the best solutions to meet your projects individual needs. Our experience in the various industries, coupled with our flexibility of our systems, has provided us with the capability to offer the most effective solutions for oily water and waste water applications. We understand the complexity of the mining, oil & gas industry, the importance of operational reliability and the daily demands faced by everyone in these industries. It is important that we understand your business,



processes and day to day requirements, this enables us to develop a high level of confidence with our customers on our products and service delivery. Our expertise range from; Water and waste water infrastructure design and supply of technologies, environmental engineering with telemetry control technology, and monitoring systems.

## **Our Goal**

Our goal within the business is to provide high quality cost effective water and waste treatment systems to all industries globally and to ensure that their effluent discharge limits are met and complied with. Oil pollution is the most common pollutant in water and it takes one litre of oil to pollute a million litres of water.

## **Our Approach**

Keeping your effluent streams clean! Our solution driven approach, locally manufactured products, technical and engineering expertise, are our strengths! This offering of technologies, coupled with skilled people and engineering; are uniquely applied to processes, water and waste water treatment to produce the best possible solutions for our clients.

## **Our products**

- Hydraspin Hydro Cyclone – oil water separation
- Electro coagulation
- Abrimix complex waste water treatment
- Sewerage treatment plants
- Reverse Osmosis plants
- Bio-chemicals: Microba and DissOil



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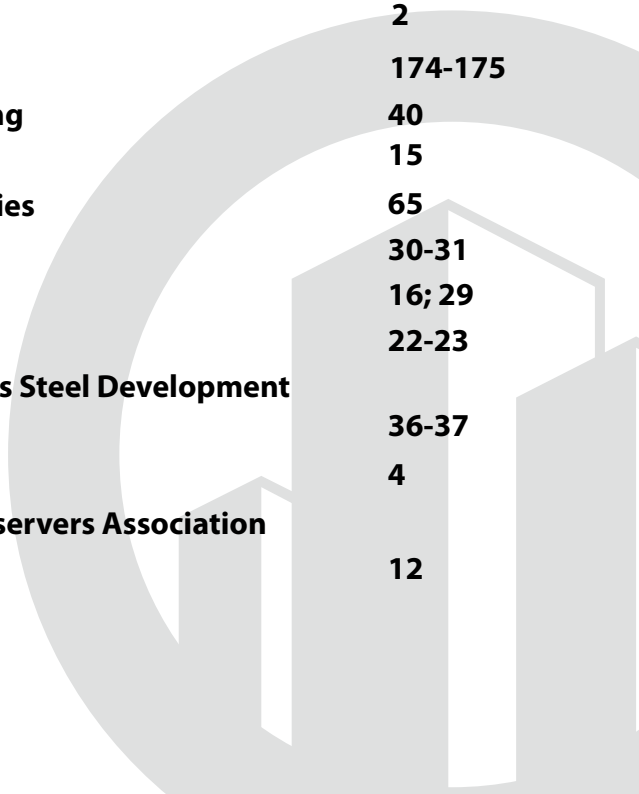
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## Innovative Recycled Rubber Solutions

### Problem:

- Approximately 160 000 tonnes of rubber tyres are discarded every year.
- Currently most of these go into landfill sites or is simply burnt.
- This results in a very negative impact on the environment.

### Solution:

- EnviroBuild turns this problem into innovative new products for re-use.
- All EnviroBuild products are 100% recyclable at end of life.
- This solution has been proven in Canada and America.



### Innovative Products from Recycled Rubber Tyres

#### • Inter-linking I-Mat

A large 1m<sup>2</sup> mat that inter links along all sides to create a strong uniform surface for pedestrian and light vehicle traffic. Perfect for driveways, playgrounds, walkways, around shopping centres, hospitals, etc. Thickness in 20mm and 35mm.

**Advantage:** Save on installation time by laying down 1m<sup>2</sup> at a time – save up to 80% on labour cost.

#### • Square Tile

A 1m x 1m rubber tile in 20mm or 35mm thickness that is durable enough for garages, workshops and gym floors. A smooth smaller 500mm x 500mm tile is also available. Decorated with a twin brick pattern.

**Advantage:** Save on installation time by laying down 1m<sup>2</sup> at a time – save up to 80% on labour cost.

#### • Conventional Pavers

Two types of pavers are available:

A 200x100 rectangular paver and a 200x160 “Dogbone” shaped paver. Both are available in 20mm, 35mm and 50mm thickness depending on your application.

#### Advantages:

- Safety – Impact when falling, Non-abrasive
- Easy maintenance – no oil absorption, no stained paving!
- Easy Installation – no dust, no noise
- Cost saving – Reduced installation time
- Weight – lighter than conventional paving; transport savings
- Does not break or crack on uneven surfaces
- 100% Recyclable
- Pending Certifications: Global Green Tag™
- SABS 51176/7 certification for playground safety

#### Applications

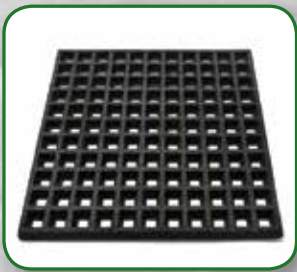
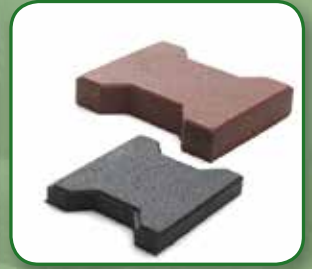
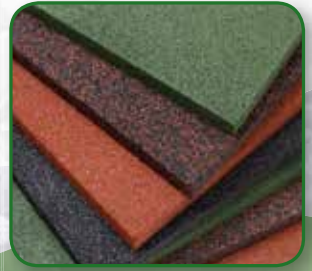
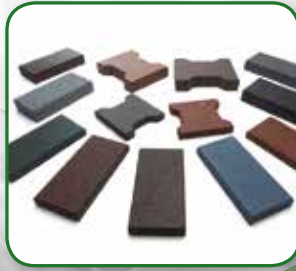
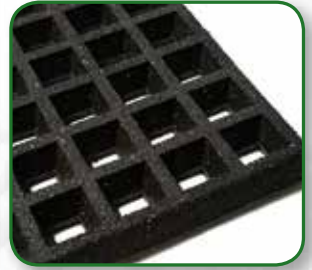
Sports Floors, Gyms, Playground Floors, Crèche, Impact Attenuating applications, Entertainment areas, around swimming pools or jacuzzi's (non-slip), Manufacturing areas, Garages, etc, etc, etc

#### Colours:

Midnight Black, Slate Grey, Redwood, Forest Green and Sky Blue.







Contact Details: Tel: 082 902 9573 • [info@envirobuild.co.za](mailto:info@envirobuild.co.za)  
[www.envirobuild.co.za](http://www.envirobuild.co.za) • [www.vandyckcarpets.com](http://www.vandyckcarpets.com)

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Shade, movement and framing of actual products may vary from sample or image. We recommend that you select your preferred slabs at the distributor nearest you.



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We manage every one of our operations with the environment in mind, measuring carbon footprints and working to reduce emissions and improve energy efficiency. Whether it's by developing advanced composite cements with low carbon footprints, or researching new approaches to water and energy conservation, we're always looking to do all we can to care for our increasingly fragile planet. For us, however, sustainability extends beyond practices and products. Social upliftment is a big part of the future too... which is why we invest deeply in developing communities in which we operate.

With this passion for social upliftment, environmental awareness and global sustainability, we're proud to be leading the way.

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Creating Concrete Possibilities



With the planet as one of our core values, we assess the carbon footprint of each and every one of our operations and products while actively striving to drive down our impact on the environment. For more information, contact the AfriSam Centre for Product Excellence or visit our website.