This guideline has been prepared through the Greening Durban 2010 Programme, an initiative aimed at ensuring the 2010 FIFA World Cup is hosted in an environmentally sustainable way, and that a positive environmental legacy is achieved from hosting the event in Durban. The Greening Durban 2010 Programme is lead by the eThekwini Municipality, Environmental Planning and Climate Protection Department.

The content of this guideline is intended for information purposes only and does not constitute legal advice. While every effort has been made to ensure the comprehensive nature of the information, the suggestions and the technologies contained herein should not be considered exhaustive. Any liability that arises or could arise from the use of this guideline is excluded.
In order to achieve the Vision, a collective conscious effort is required by all the citizens of the eThekwini Municipal Area to address and rectify the problematic issues facing the region and the country. Of all these challenges, there is one that negatively impacts the very foundation upon which we base our existence: environmental degradation and unsustainable development.

Although human beings have achieved much over the last few hundred years, this has come at a significant environmental cost. Globally, over the last 150 years we have managed to burn much of the planet's fossil fuel resources, extract many available minerals to the point of exhaustion, and consume or destroy much of its biomass and biodiversity. In doing so, the levels of land, water and air pollution have continued to rise! In South Africa, the development and operation of South Africa's built environment is responsible for approximately 40% of the country's energy consumption, whilst 25% of South Africa's landfill waste is derived from construction and demolition waste.

The World Wildlife Fund's 2006 Living Planet Report states that humanity's ecological footprint, our impact upon the planet, has more than tripled since 1961!!

The result is an increasingly polluted planet that's ability to absorb the negative changes and return to a state of relative equilibrium whilst maintaining liveable conditions for much of the species that inhabit it, is seriously under threat.

Unless there is a paradigm shift in the way in which we choose to develop, we are heading into a future where, at best, the free life essential services provided by the natural environment will have to be supplemented, perhaps replaced, by manmade industrial services at a cost we simply could not afford!

A modern transparent and informed approach is required to enable us to counteract these issues. It is essential that the current general underlying belief that all development of the built environment must have negative effects, be converted to an understanding of the necessity to design for improvement in the health and prosperity of both ourselves as a species and our encompassing environment on which we are so inextricably dependant. In addition, whilst it is critical that we continue to strive for our current sustainable development aspirations of minimal impact, alone it will not be enough. For in order to offset certain inevitable negative effects of an ever expanding urban population, we need to implement positive development that enhances urban space for both people and natural processes and hence improve human and ecological health, resilience and viability.

Whilst there's definitely a need for more than just concern, there's reason to be positive. More and more environmentally friendly products are being manufactured. Concerned architects, engineers, inventors and people from all walks of life are working together to create ways in which to lessen our ecological footprint. Many organisations are choosing to operate according to sustainable development principles. Some progressive cities are making it mandatory for all new inner city developments to be certified environmentally friendly (www.cityofchicago.org). Entire city precincts, such as Masdar City in Dubai, are being designed according to environmental sustainability principles. Green Building Councils have been set up in many developed and developing countries, including South Africa, to encourage more environmentally friendly building methods (www.gbcsa.org.za).

The increasing cost of energy and the necessity for a reliable supply of electricity in particular, is the catalyst which will stimulate wider implementation of intelligent building design and operation in South Africa. It is apparent that the rising cost of energy will put increasing pressure on the economic sustainability of existing buildings unless better energy management is implemented. For those wishing to develop property, there is the very real prospect that a development may not be guaranteed a grid electricity supply unless it is designed to be energy efficient.

Bearing all of the above in mind, it is clear that buildings within the eThekwini Municipal Area must become energy and resource efficient. The problem is that the issue has only recently become 'mainstream' in South Africa, and subsequently there is a general lack of knowledge on methods to successfully implement the great design maxim: as much as necessary, as little as possible.
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Planning

“To accomplish great things, we must not only act, but also dream; not only plan, but also believe.”
Anatole France, Nobel Laureate.

As with any successful project, planning is an essential component. Green Building, of which energy efficient building is an extremely important component, requires making decisions based on the lifecycle performance of a building with respect to economic, social and environmental factors. This section covers some of the key planning considerations that one needs to be aware of.

1.1 Costing

<table>
<thead>
<tr>
<th>Capital Expenditure (Capex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Buildings do not necessarily have a higher capital cost than conventional buildings. Although, until they become the norm they may have a higher overall design cost, their improved design will require less from the artificial, or active, building systems to achieve the same level of performance.</td>
</tr>
<tr>
<td>In addition, it is important for building owners to understand the benefits of a building where the design is significantly influenced by the lifecycle cost of its components, as opposed to conventional designs whereby initial capital expenditure is the overriding concern.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational Expenditure (Opex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced load on utility services and the respective bills is one of the key benefits of successful Green Buildings; in the greater scheme of things, the reduction in resource consumption is a major rationale for Green Building.</td>
</tr>
<tr>
<td>Maintenance costs for energy efficient buildings may, or may not, be lower than their conventional counterparts and needs to be assessed on a project-by-project basis.</td>
</tr>
<tr>
<td>This is due to the fact that although the artificial, or active, building systems may be of a smaller size in energy efficient buildings, they are often required to be kept in optimum working condition resulting in higher maintenance costs per unit of capacity.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Human Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>The cost of human labour is typically the major operating cost of a business and although it can be difficult to accurately quantify the benefits of an improved indoor environment quality on human well being, it is common knowledge that human well-being is directly proportional to productivity. Thus, it makes economic sense for employers to ensure that their employees work in a quality environment.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Professional Design Fees</th>
</tr>
</thead>
<tbody>
<tr>
<td>The way in which professionals structure their fees with respect to Green building services can cause a certain amount of confusion and become a stumbling block with respect to a creating a successful integrated design team. The most common fee structures are as follows:</td>
</tr>
<tr>
<td>1) <strong>System/Construction cost based design fees</strong>: Fees based on a percentage of the system or construction cost, although easy to quantify, do not necessarily produce the best results with respect to overall project performance. In fact, this type of fee structure is more likely to lead to unnecessarily large and expensive systems or designs.</td>
</tr>
<tr>
<td>2) <strong>Fixed fees</strong>: Fixing the amount a design professional will be paid before commencing any work is hardly an incentive for excellence in Green Design. However, it does remove the incentive for unnecessarily large and expensive systems or designs.</td>
</tr>
<tr>
<td>3) <strong>Premium and Performance based fees</strong>: Motivation for design excellence can be created by offering incentives, above the normal fee rate; when using this fee structure it is important to set target ranges relevant to the level of incentive.</td>
</tr>
</tbody>
</table>
1.2 Project Goals

As early as possible, a well-rounded and integrated Project Team must be established that comprehends the interactions of a building, its occupants and the surrounding environment, and is capable of designing accordingly.

The Project Team must be capable of formulating informed Project Goals that include:

- Designing for energy and water efficiency.
- Designing for occupant safety.
- Designing for optimal occupant productivity i.e. healthy indoor air quality, natural lighting and thermal comfort.
- Integrating on-site sustainable energy generation.
- Conservation/improvement of topsoil and site biodiversity.

These Project Goals will be extremely influential on:

- Siting
- Design
- Equipment and material selection
- Financing
- Construction
- Long-term operation of the building

Although these Project Goals should be reviewed at several stages throughout the Project, it is important that the Project Team follow the integrated design strategies emerging during pre-design and conceptual design sessions.

1.3 Services

Buildings are highly dependent on services such as the provision of energy and water as well as waste removal. Problems related to urban sprawl, energy and water supply in addition to waste removal necessitates that comprehensive planning, with respect to the provision of these services, is conducted in the initial stages of a project. In addition, understanding the potential issues related to the provision of these services may affect the project’s desired performance requirements.

Equipment related to these services is often considered unsightly and hidden from general view in poorly designed, difficult to access areas of a building. This approach can inadvertently lead to neglect and mismanagement of the equipment which in turn leads to poor performance and inefficiency.

Although decisions relating to the building’s aesthetics are beyond the scope of this document, it is important to ensure that equipment requiring maintenance be placed in well ventilated and easily accessible areas.

The Pompidou Centre in Paris is a great example of a building that utilises the infrastructure of necessary services to supplement its aesthetic design to great effect. (see www.en.wikipedia.org/wiki/Centre_Georges_Pompidou).
1.4 Management

The benefits of Green Buildings are most effective when their occupants and operational staff understand how to use them correctly. Therefore, it is extremely important that the following management tasks are implemented in an energy efficient building:

2) Commissioning of the building’s systems.
3) Fine tuning of building systems over the course of the year.

1.4.1 Building User Guide

The behaviour of building users plays an extremely important role in achieving overall energy efficiency within a building. Thus, it is important that the correct operation of user controlled building systems is widely understood, and easy to do.

A ‘Building Users Guide’ can be developed and made available to all persons that spend time within the building and its grounds. The document should not be a detailed systems operation and maintenance manual but rather a simple document that can be thoroughly understood by the layman.

The document should cover the following sections:

- Health and safety.
- Building systems; including HVAC, lighting and water heating.
- Transport facilities available.
- Waste management and recycling facilities.
- Recommendations for environmentally friendly daily operations.
- Contact details for Building Manager and Maintenance Personnel.
- References and further information.

Occupants should be encouraged to undergo an orientation process that incorporates tasks related to the information within the Building Users Guide; the process should be repeated on a yearly basis in order to maintain performance.

1.4.2 Commissioning

The commissioning process is a formal method of reviewing and integrating all of the project goals intended during planning, design, construction, and occupancy phases. It is performed by inspection and functional performance testing, ensuring that the respective building system operators undergo the necessary training and receive the necessary manuals to efficiently operate and accurately record system performance. During the process any deviations from expected building performance should be uncovered, documented and corrected by those responsible. The commissioning process should wherever applicable comply with the ASHRAE Commissioning Guideline 1-1996 for mechanical services and CIBSE Commissioning Codes for all other services.

Once the process has been completed and all deviations corrected, the building should accomplish the project’s goals which should include higher energy efficiency, occupant safety, healthy indoor air quality and environmental health.

Building performance often decreases 1-5 years after initial occupancy. Therefore it is important that building owners and managers be aware of the need and commit to a retrocommissioning proc-
Building systems should be fine tuned at least every 3 months in order to adjust to changing climatic variables and occupancy characteristics. A record should be kept of all changes and their effects assessed with respect to building performance.

1.5  Pre-design Considerations

1.5.1  Durban’s Climate

Climatic conditions generally vary from one location to another, conditions prevalent in Durban are not necessarily the same as those slightly further inland and it is best to obtain site specific data wherever possible. However, since Durban is the major city within the eThekwini Municipal Area, this section covers the general macro-climatic conditions specific to the City and the immediate coastal areas; the information will be particularly useful when conducting climate resource calculations and applying the design strategies covered later in the chapter.

1.5.1.1  General Description

Durban falls within a sub-tropical coastal zone, meaning that in terms of its macro-climate, generally:

- **Summer**: fine weather is associated with north-easterly winds, high temperatures and high levels of humidity. This is interrupted by the eastward progression of coastal low pressure systems and occasional cold fronts, which are accompanied by a switch to south-westerly winds, rainfall and a decrease in air temperature.

- **Winter**: prolonged periods of calm weather can be experienced when high pressure cells dominate the interior. During these periods of calm, cold light north-north-westerly winds prevail in the early mornings with low levels of humidity, swinging to light north-easterly winds by midday. These periods of calm weather are often interrupted by the eastward progression of cold fronts, which are accompanied by a switch to south-westerly winds, a decrease in air temperature and occasionally rainfall.

In addition, highly urbanised areas such as Durban’s CBD have a significant amount of concrete buildings that act as a heat sink, this leads to higher temperatures than would otherwise be experienced. Fortunately, on the beachfront there is a land-sea air exchange which tempers the effect.
1.5.1.2 Solar Resource

The Sun’s daily position in the sky differs over the course of the year. As a result, objects looking to maximise the use of solar energy, such as building thermal mass, photovoltaic (PV) panels and solar water heaters, should be orientated at the optimum angle for intended yearly time of use. The best angle for overall annual solar energy harvesting is 35° to the horizontal. However, the fixed angle should vary according to which time of year is chosen for energy optimisation i.e. 0° for maximum energy over the peak summer months and 65° for peak winter months.

The table below illustrates the average solar energy available over the course of a year, whilst the chart illustrates the average hourly change in available solar energy over the course of a day.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>5.53</td>
<td>5.40</td>
<td>4.89</td>
<td>3.99</td>
<td>3.28</td>
<td>3.03</td>
<td>3.17</td>
<td>3.62</td>
<td>4.02</td>
<td>4.77</td>
<td>5.15</td>
<td>5.74</td>
</tr>
<tr>
<td>35°</td>
<td>5.00</td>
<td>5.31</td>
<td>5.49</td>
<td>5.31</td>
<td>5.01</td>
<td>5.11</td>
<td>5.12</td>
<td>4.76</td>
<td>4.90</td>
<td>4.78</td>
<td>5.06</td>
<td>5.08</td>
</tr>
<tr>
<td>65°</td>
<td>3.49</td>
<td>4.04</td>
<td>4.68</td>
<td>5.14</td>
<td>5.26</td>
<td>5.61</td>
<td>5.50</td>
<td>4.27</td>
<td>3.90</td>
<td>3.42</td>
<td>3.42</td>
<td>4.48</td>
</tr>
</tbody>
</table>

1.5.1.3 Wind Resource

The wind power potential in the general Durban region is considered moderate. Highest average monthly wind speeds occur in October and lowest occur in June. There is a strong diurnal cycle in both winter and summer with peak wind speeds occurring in the early afternoon. Dominant wind directions are NE and SW.

Tip: To estimate the kilowatt hours of energy available from a solar device for a specific time period, multiply the exposed surface area of the device by the relevant available solar energy, in kilowatt hours per square metre, over the specific time period. Finally, in order to take into account the efficiency of energy transfer, multiply the first answer by the efficiency of the device.

\[
\text{Power (kWh)} = \text{area (m}^2) \times \text{energy (kWh/m}^2) \times \text{Eff}_{\text{device}}
\]
This wind rose information was recorded at Durban’s Airport, south of the City.

The information is directly applicable to the City and the immediate coastal areas.

Wind conditions will increasingly vary the further a location is from the coast, wherever possible site specific reliable wind data should be obtained prior to design.
Tip: Wind power is proportional to wind velocity cubed, therefore to estimate the power available, in kilowatts, multiply the exposed surface area of the device by the density of air and the wind velocity cubed. Finally, in order to take into account the efficiency of energy transfer, multiply the first answer by the efficiency of the device.

$$Power\ (kW) = area\ (m^2) \times density\ \left(\frac{kg}{m^3}\right) \times \left(velocity\ \left(\frac{m}{s}\right)^3\right) \times Eff_{device}$$

1.5.1.4 Humidity

Due to Durban’s location adjacent to the warm Indian Ocean, which supplies the City with warm moist air, the relative humidity levels are fairly high, particularly in the warmer summer months when the air has the capacity to hold higher levels of moisture.

The data in the table below was recorded at Durban’s Airport, south of the City. The information is directly applicable to the City and the immediate coastal areas.

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH%</td>
<td>70</td>
<td>70</td>
<td>68</td>
<td>65</td>
<td>61</td>
<td>54</td>
<td>56</td>
<td>60</td>
<td>66</td>
<td>69</td>
<td>71</td>
<td>69</td>
</tr>
</tbody>
</table>

1.5.1.5 Rainfall

Durban is considered a summer rainfall area since approximately 60% of the annual precipitation occurs between the months of November and March. Extremely heavy downpours are common in summer and too often results in flooding, landslides and damage to poorly designed built environment infrastructure unable to cope with the intensity of rainfall.

The data in Table 3 was recorded at Durban’s Airport, south of the City. The information is directly applicable to the City and the immediate coastal areas.

Conditions will increasingly vary the further a location is from the coast, wherever possible site specific reliable data should be obtained prior to design.
A site analysis should be undertaken to assess the following site specific conditions:

**Bio-physical preconditions:** the effects of macro-climatic weather conditions on topography and vegetation of a site create a site specific micro-climate influenced by the following:

- Solar radiation
- Wind
- Water catchment and drainage
- Existing biodiversity
- Soil conditions
- Air quality
- Noise pollution
- Natural hazards

**Pre-existing infrastructure:**
- Property zoning
- Power supply
- Water supply
- Sewerage reticulation
- Access to transport routes and public transport

**Other factors:**
- Flight paths
- Electromagnetic interference
- Vibration; railroads, major roads, construction etc
- Proximity to workforce
- Proximity to workplace
- Local building resources

### Table 3: Durban rainfall data

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly mean (mm)</td>
<td>134</td>
<td>113</td>
<td>120</td>
<td>73</td>
<td>59</td>
<td>28</td>
<td>39</td>
<td>62</td>
<td>73</td>
<td>98</td>
<td>108</td>
<td>102</td>
<td>1009</td>
</tr>
<tr>
<td>No. of rainy days</td>
<td>15</td>
<td>13</td>
<td>13</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>11</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>130</td>
</tr>
<tr>
<td>Max in 24 hrs</td>
<td>110</td>
<td>197</td>
<td>160</td>
<td>106</td>
<td>111</td>
<td>109</td>
<td>69</td>
<td>91</td>
<td>132</td>
<td>105</td>
<td>94</td>
<td>163</td>
<td>197</td>
</tr>
</tbody>
</table>

Tip: To estimate the volume of rain water runoff, calculate the surface area of the two dimensional space in question (water catchment surface) and multiply by the relevant rainfall ensuring that you convert all units to metres prior to multiplication. This will leave you with cubic metres and 1 cubic metre is equivalent in volume to 1000 litres.

\[
\text{Volume (m}^3\) = \text{horizontal area (m}^2\) \times \text{rainfall (m)} \\
\text{Volume (l) = volume (m}^3\) \times 1000
\]

### 1.5.2 Site Analysis

Although each site needs to be analysed in terms of its micro-climatic features, a general rule for energy efficient building in the southern hemisphere is the orientation of the building along an east-west axis where the predominant façade faces north, maximising the potential natural lighting and thermal regulation.

For energy efficiency in a warm climate, solar access and air flow is strongly correlated to form and massing. It is vital to orientate plan and windows to enhance ventilation whilst avoiding excessive heat gain.

### Figure 7: Correct orientation

Optimum Orientation
S-Hemisphere
1.5.4 Form

The form of a building should correlate to the required heating and cooling, natural ventilation and natural lighting of spaces according to their functions.

Cooler temperate regions may employ a more compact form whilst hotter humid climates, a more open or elongated plan form. The reason for this is that the size of the surface area of the building envelope is directly proportional to the amount of solar heat gain and thermal loss. Elongated open plan forms allow for adequate air movement and insulation requirements are lessened.

Compactness is expressed by the area to volume (a/v) ratio. In practice, it is often necessary to compromise between a slightly unfavourable a/v ratio and a preferred design concept that has advantages with respect to other key project requirements such as plan layout, more ergonomic use of space etc.

The diagram above illustrates the key design considerations relating to form when designing for a cool climate compared to a warm humid climate such as Durban’s.

- The cool climate model attempts to maximise solar gain on all 3 facades, hence its compact sides ratio of 1:1:1.

- The optimum plan form for a warm and humid climate is given as a ratio of 1:1.7. The east and west facades are smaller to minimise the associated heat gains from the low angle morning and afternoon sun, whilst the north and south facades are elongated to ensure adequate daylighting and natural ventilation.

1.5.5 Specification of Products, Materials and Technology

Deciding which products, materials and technology (all hereinafter described as products) to specify in a Green Building can be a daunting task. Although there is definitely value in specifying products whose existence is significantly motivated by environmental objectives, it is important not to be drawn into the trap of specifying certain products based purely on their perceived environmentally friendliness without comprehensive knowledge of their envisaged triple bottom line performance. Failure to do so, knowingly or unknowingly, will likely lead to a ‘greenwashed’ project and poor overall building performance.

So what should owners, developers, designers, engineers and other building practitioners look for in an environmentally friendly product?

Products should be assessed based on the triple bottom line implications of their use over the complete lifecycle of the product or ‘cradle-to-grave’.
In addition to the commonly considered capital and operating expenditure of products, assessment of the following is critical:

**Embodied energy**
It is important to specify products which will realise low embodied energy over the full lifespan of the building.

Embodied energy is the upstream component of the lifecycle impact of a material and is calculated by summing all the energy consumed by the processes required to produce the product*. Typically, these include the energy associated with mining, agriculture and transport. All of which are currently derived from fossil-fuels which are responsible for a significant amount of human induced climate change.

* Embodied energy does not include the energy associated with the operation of the building and disposal of the material.

**Durability**
A product needs to have sufficient structural strength for its required lifespan.

Note that in this case ‘required lifespan’, does not necessarily mean the full lifespan of the building. It may well be that certain products are planned for replacement at a certain stage, however it is important to minimise the overall environmental cost over the full expected lifespan of the building.

**Toxicity**
Since the majority of building materials are likely to end up in landfill at some time or another, it is important to specify products that neither contain nor are manufactured using significant quantities of ecologically toxic elements, in particular:

- Persistent organic pollutants
- Carcinogenic compounds
- Bio-accumulative compounds
- Hormone disrupting compounds
- Mutagenic compounds
- Teratogenic compounds

**Recyclability**
Products that have the ability to be recycled into a future project with minimal reprocessing have significant potential environmental benefits.

---

*Image: Diagram illustrating embodied emissions at various stages of a lifecycle.*
This approach to building design has developed numerous descriptions including bioclimatic design, passive design, low energy building and climate responsive design. Regardless of the terminology, the common ideology is to obtain conditions of internal comfort through the utilisation of the surrounding natural environment whilst reducing the requirement for artificial, or active, systems to provide heating, cooling, ventilation and lighting.

Be aware that the idea should not be to focus on designing a building that utilises only natural lighting or only natural ventilation, but to incorporate a range of passive design concepts in a well balanced manner in order for the building to respond effectively to fluctuating climatic conditions. When successful, the end result, with respect to energy efficiency, is a building with a minimum requirement for utility supplied energy and tremendous operational cost savings over its lifespan. In order to be successful, the design team requires a thorough understanding of climatic and micro-climatic phenomena such as solar radiation and positioning, wind, humidity, and rainfall in terms of their effect on the building, in particular the building envelope.

The building envelope is comprised of those elements that define space, marking the inside from the outside. In terms of passive architectural design it is the component with the most profound effect on a building’s indoor environment.

To be truly energy efficient, the building envelope should function as an intelligent skin, responsive to varying user activities and climatic factors.

The key design considerations for an energy efficient building envelope should be how it responds to fluctuating levels of temperature, humidity, solar radiation and wind to provide optimum user comfort with its associated benefits on productivity, health and overall wellbeing. By maximising user comfort through integrated passive design strategies and a high performance facade, as well as appropriate materials and construction techniques, the artificial lighting and HVAC system capacities required as well as their respective capital and operational costs will be reduced.
Figure 11: The role of the building envelope as an interface between internal and external conditions and requirements.
Buildings that are able to maximise levels of thermal comfort through passive architectural design, require less energy intensive artificial, or active, systems to achieve optimum levels of thermal comfort.

Thermal comfort levels in a building are dependent on a combination of climatic and user variables as illustrated in the diagram below.

**Figure 12: Factors influencing thermal comfort**

The four main passive heating and cooling strategies are ventilation, evaporative cooling, thermal mass and thermal mass with night ventilation.

- **Comfort ventilation**: the movement of air through a building to regulate thermal comfort.
- **Evaporative cooling**: usually used in hot dry climates where water is introduced at some point to humidify and cool the air.

Usually needs to incorporate ventilation principles.

- **Thermal mass**: is the phenomenon whereby materials with high thermal mass are used to regulate the fluctuations in temperature.
- **Thermal mass with night cooling**: provision must be made for the heavy mass elements to re-radiate heat back into the atmosphere at night producing a cooling affect.
Analysing climatic data and interpreting it with regard to building design was developed by Belgian architect Victor Olgyay in the 1960’s. It has evolved into an intricate science and is an effective method of determining which passive design strategies will work for a given building in a specific climate.

The visual interpretation of this climatic data in relation to building approach is known as a ‘Bio-climatic Chart’. The chart depicts the major climatic influences of temperature, humidity, radiation and air movement on the user.

In order to utilise the Bioclimatic Chart it is necessary to first plot the climatic conditions for the area. The following is a list of the steps required:

1) Plot each month’s relative humidity high with its respective dry bulb average monthly low.
2) Plot each month’s relative humidity low with its respective dry bulb high.
3) There will be 2 points for each month which need to be joined by a straight line and labelled with their respective month.

**Figure 13: Bio-climatic Chart illustrating passive design strategies for Durban**
Understanding the Bio-climatic Chart:

1. In the centre of the chart, represented by the blue zone, is a pre-determined comfort zone where ideal conditions for human comfort are experienced.

2. The four passive design strategies are each represented by a coloured zone on the chart and have predefined parameters.

3. The large rectangular zone, indicated by the green zone, represents conditions that exist below ideal comfort levels. As the temperature increases towards the comfort zone, less solar radiation is required to heat the building.

4. As the relative humidity increases along the horizontal plane of the chart, so too does the need for shading and natural ventilation.

5. Wherever the monthly plotted line intersects with a passive design strategy zone/s indicates which strategy/strategies is/are suited to the climate for that month.

Bio-climatic analysis for Durban:

1. The monthly plotted lines for Durban indicate that shading and a natural ventilation strategy will best achieve user comfort. The reason for this is the high level of relative humidity we experience. Cross ventilation and displacement ventilation are described in the following section and are the fundamental components of providing comfort in humid conditions.

2. North facing elements with high thermal conductivity values need to be shielded from direct sun to prevent overheating of the structure.

3. Large overhangs and other solar shading devices are required to perform this function. Thermal mass principles may be utilised in certain winter months but for the most part excessive heating of thermally conductive materials like concrete, steel and masonry should be avoided.

4. Thermal stacks like the ‘solar chimney’ provide movement of air required for comfort in humid climates.

5. When a passive strategy cannot provide optimum user comfort alone, the use of integrated passive and active ventilation systems are required.

The same methodology applied with the Bio-climatic Chart can be achieved utilising a psychrometric chart.

In addition, modern building simulation software has the potential to enable accurate assessment of a building’s envisaged performance prior to construction making it an extremely useful tool during the design phase. More detailed information on the benefits of simulation software is addressed later in the document.

2.1.2 Ventilation

Ventilation, in the context of this document, is defined as the movement of air throughout a building space.

The three main functions of ventilation are to provide:

1) Adequate levels of quality fresh air that will replace or dilute the level of indoor pollutants.

2) Comfort ventilation by encouraging evaporation of moisture from the skin and in doing so cooling the body; extremely important in warm humid climates.

3) Structural cooling or heating via the thermal exchange between the air and the building structure.

The passive design response to the above functions of ventilation is largely dependent on the sites’ microclimate and overall context. In addition to the primary direction of prevailing winds, the local topography, trees and elements of the urban fabric will each have their effect on the site specific direction and velocity of airflow.

Once the site analysis has been conducted, the following key considerations should be taken into account when designing buildings with natural cooling systems based on comfort ventilation:

1) Building orientation and spacing

2) Building orientation and position of openings

3) Operability of openings
2.1.2.1 Building orientation and spacing

Buildings in parallel rows, relative to the prevailing wind direction, creates ventilation shading. For maximum natural ventilation rates they should be staggered.

Building openings should be of suitable size and should be orientated to enable natural airflow from the windward to the leeward side. A building should not have too deep a plan and should be relatively free of major obstructions within the interior.

Buildings spaced too closely together create unpleasant wake and vortex effects. The distance between buildings, in the direction of site specific prevailing winds, should be 5 times the height of the windward building.

Figure 14: Correct spacing of buildings for natural ventilation

Buildings in parallel rows, relative to the prevailing wind direction, creates ventilation shading. For maximum natural ventilation rates they should be staggered.

Figure 15: Spatial configuration for ventilation availability

Building openings of the same size orientated on exact opposite sides of the room, without side openings, may not enable thorough ventilation of the space leaving pockets of stagnant air.

Figure 16: Flow through a building ventilated by windward & leeward windows
Disproportionate sizes of openings will create regions of greater air flow (represented by grey areas). Buildings with no openings on the leeward side of the building will create vortex effects on the leeward side of the building.

A building with inadequate openings on the windward side or all openings on the leeward side is likely to have poor natural ventilation.

Disproportionate sizes of openings will create regions of greater air flow (represented by grey areas).

Heat exhaust systems, such as solar chimneys and roof ventilators, allow internal heat to rise and escape from the building. At the same time fresh air is drawn into the building through openings in the building envelope. In addition, they can enable natural light into the building.
2.1.2.3 Operability of openings

A building with fixed openings cannot adapt as easily to changing climatic conditions due to its inability to vary the amount and direction of natural ventilation required. Therefore, buildings looking to utilise natural ventilation should have varying sizes and orientations of operable doors, windows and vents in order to easily adapt to changing conditions.

Figure 21: Operability of openings

![Operability of openings](image)

Double hung window: Top and bottom equally open results in horizontal airflow.

Double hung window: Bottom or top open results in a slightly deflected airflow.

Projection/awning window deflects air upwards.

Louvers: Air moves at approximately same angle as louvers.

2.1.2.4 Adaptability of the building façade

The façade may consist as a combination of opening types which may be used alone or together to provide views, ventilation, privacy and protection from wind, rain, sun and pests. The following images depict variations to the façade in order to achieve the desired effect.

Figure 22: Sliding glass panel provides light and air

![Sliding glass panel](image)
Due to the high relative humidity levels in Durban, an energy efficient ventilation system is likely to require an integrated design approach encompassing both active HVAC and natural ventilation components. However, wherever possible designers should seek to reduce the capacity of energy consuming HVAC equipment required by designing buildings that take full advantage of the positive attributes of natural ventilation.

The following images depict common ventilation options found in buildings and the respective air flows.

### 2.1.2.5 Examples of integrated passive and active ventilation systems

Due to the high relative humidity levels in Durban, an energy efficient ventilation system is likely to require an integrated design approach encompassing both active HVAC and natural ventilation components. However, wherever possible designers should seek to reduce the capacity of energy consuming HVAC equipment required by designing buildings that take full advantage of the positive attributes of natural ventilation.

The following images depict common ventilation options found in buildings and the respective air flows.

**Figure 23:** Closed glazing provides views and light whilst preventing dust, rain and insects

**Figure 24:** Sliding opaque louvers provides ventilation whilst protecting from sun and rain

**Figure 25:** Sealed against driving winds and rain

**Figure 26:** Mesh screens allow views and ventilation whilst preventing insects

**Figure 27:** Window ventilation

- **Thermal aspects:** Air supply temperature dependant on weather.
- **Advantages:** High user acceptance, fresh air, low cost.
- **Disadvantages:** Noise entry, no heat recovery.
- **Typical use:** Residential, schools & offices.
Thermal aspects: Defined supply air tempering.
Advantages: Low space requirement and can be retrofitted.
Disadvantages: High maintenance & high energy.
Typical use: residential, conference, & office.

Thermal aspects: Useful in winter but in danger of overheating in summer.
Advantages: Fresh air intake and one set of ducts.
Disadvantages: Possible noise and odour transmission from the atrium.
Typical use: Cafeteria, offices & conference rooms.

Thermal aspects: Supply air temperature may be uncomfortable in summer, atrium must be ventilated.
Advantages: High user acceptance, fresh air, low cost.
Disadvantages: Excessive heating of atrium if not ventilated causing possible return air flow from the atrium.
Typical use: Offices.
Natural lighting for buildings located in hot climates requires consideration of both the need for natural light* and the heat gain associated with direct solar radiation. Natural lighting can be broken down into direct, diffuse and reflected light with the objective being to use natural diffuse light to avoid excessive use of artificial lighting, and the associated heat gain linked to their usage.

Important design criteria for an effective natural-lit space:

- Adequate and uniform light distribution.
- Avoidance of excessive heat gain.
- Avoidance of disabling glare and minimization of contrasting glare.

Means of achieving design criteria:

1. Orientation.
2. Planning of naturally-lit spaces according to their functions.
3. Dimensions of openings.
4. Ratio of glazing in the façade.
5. Window location and orientation.
6. Level of reflectance.

* Although there are minimum SABS standards that regulate the minimum area of openings for natural day lighting, optimal lighting systems need to be designed in conjunction with heating/cooling and natural ventilation systems to ensure the harmonious integration of functions carried out by the building envelope.
Diffuse sunlight results in the following:
- Soft lighting - no glare.
- Even distribution of light.
- Low heat gain.

Indirect sunlight results in the following:
- Reduced glare.
- Less contrast created by shading.
- Reduced heat gain.

2.1.3.1 Orientation

The orientation of the façade is an important design consideration.

- North light is required for good natural lighting but in Durban, needs to be protected from intense summer sun and the ratio of glazing to solid elements needs to be carefully considered.
- East and west lit spaces need to control glare from lower angle sun paths.
- South facing facades will receive very little direct lighting and the ratio of glazed elements to solid elements may be increased.

2.1.3.2 Planning of naturally-lit spaces according to their function.

Varying user activities requires different lighting levels and spaces should be designed accordingly.

2.1.3.3 Dimensions of openings

The dimensions of openings as well as the floor-to-ceiling height versus depth ratio will influence daylight penetration into buildings. As a rule of thumb, an effective daylight penetration ratio is roughly 2.5 times the floor or window height.
The ratio of the glazing in the façade varies, along with the required lighting levels, according to the function of the building space. In addition, the type of glazing can have an important effect as heat resisting glass also reduces daylighting levels.

**2.1.3.4 Ratio of glazing in the façade**

As a rule of thumb, if the glazing fraction is higher than 50%, temperature levels become excessive and shading is required.

These two graphs exemplify the varying amount of heat gain associated with different glazing fractions on the north façade of an office building.

As a rule of thumb, if the glazing fraction is higher than 50%, temperature levels become excessive and shading is required.
Variations in placement and height of windows relative to the spatial requirements achieve different effects. For example, longer vertical windows can achieve better daylighting than a horizontal window of the same size depending on the orientation of the building.

**Figure 41: Daylight factor (D) in relation to window position and distance to the window.**

![Graph showing daylight factor (D) in relation to window position and distance to the window.](image)

Essentially what the graph illustrates is that the higher the opening is located in the façade, the further the penetration of light into the space.

**2.1.3.6 Level of Reflectance**

The level of reflectance in the room is important in controlling glare and the light distribution in the room. A light-coloured floor makes the space appear brighter and may improve luminance levels in situations where verandas and external rooms have increased the plan depth.

Intelligent use of vegetation may be used to filter the amount of direct sunlight striking a surface. Deciduous trees shed their leaves in winter allowing more light through, whilst evergreen trees maintain their leaves throughout the year.

**Figure 42: Reflectance and diffuse lighting for north façade**

**Figure 43: Effect of vegetation on reflectance and diffuse lighting for east and west facades**
Various natural lighting devices can be integrated into a building design to enable natural light into otherwise hard-to-reach spaces and to regulate levels of solar heat gain.

A few examples of devices commonly used are:
- Solar shading - see section 2.1.5.3
- Light shelves - see section 2.1.5.4
- Skylights - see section 2.1.5.5

BPS software has the potential to enable accurate predictions of building performance prior to actual construction and can be extremely useful in analysing building options during the conceptual design stage.

It is important to understand that a simulation requires a variety of accurate inputs in order to accurately predict performance, thus it follows that inaccurate inputs will reveal inaccurate predictions. That said, accurate building performance simulation generally offers exceptional value for money and can reveal many unknowns when designing a Green Building; the cost of simulation is miniscule compared to rectifying errors in system design.

Although there are a large variety of software programs available and many have their areas of specialization, most perform the following functions to varying degrees of effectiveness:

- Simulation of passive building design performance according to real local hourly weather data.
- Simulation and calculation of active HVAC heating and cooling loads.
- Simulation of complete building model to verify how the building will behave under actual operating conditions including:
  - Thermal comfort and heat transmission through building fabric including walls, roofs, infiltration, ventilation etc.
  - Energy requirements, by fuel and end-use
  - GHG emissions
  - Lighting
  - Shading
  - Acoustic analysis
  - Ventilation

**Figure 44: Summary of passive design strategies and interaction with active mechanical systems**
I am strongly convinced that it is possible to design buildings and cities that would not only have a less negative impact but a net positive influence on their environment. That's better than zero waste!

Dr Janis Birkeland; Architect, Lawyer, Environmental Planner and Professor.

Passive building design entails understanding and utilising local climatic and site conditions with the intention that buildings respond effectively to climatic conditions in order to achieve maximum occupancy comfort with minimal requirement for artificial, or active, indoor environment control.

Owing to the fact that the application of passive design will only go so far as to reduce some of the inherent negative impacts of built environment development, the inclusion of positive development features such as those arising from ecologically provided services design, eco-design, is increasingly important.

Eco-design entails the use and inclusion of natural ecology within the building design in order to achieve maximum occupancy comfort with the added benefit of increasing natural biodiversity and, in doing so, improving the environment.

Passive and ecologically provided building services are supplied at little or no operating cost. When considering the economic, social and environmental cost of utility services over the full lifespan of a building it makes sense to utilise passive and eco-services. Unfortunately, too often building developers are unconcerned with lifecycle costs, leaving occupants to suffer the consequences of poor design.

The following section includes a few, of many, examples of passive and eco-design that utilise natural systems to good effect. The list of examples included is:
- Roof example - Green Roofs
- Wall example – Living Walls
- Façade example – Solar Shading
- Natural lighting example – Light shelves
- Natural lighting example – Prismatic Skylights
- Natural ventilation example – Solar Chimney

**2.1.5.1 Roof example - Green Roofs**

**Description**

A Green Roof, as the name suggests, is a rooftop with a vegetation covered surface. The roof surface needs to have a suitable gradient and should be strong enough to support the added weight *. It is important to ensure that water is able to drain off the planted surface without compromising the function of the roof surface. Indigenous drought and wind resistant plants should be planted in a specialised growing substrate that is lightweight, is able to retain moisture and yet facilitates drainage of excessive water.

**Typical applications**

Since the benefits of Green Roofs are particularly beneficial to urban environments they are most applicable to flat and slightly pitched roofed buildings in urban areas.

* The roof should be inspected by a structural engineer prior to constructing a Green Roof.

eThekwini Municipality’s Environmental Planning & Climate Protection Department is piloting a Green Roof project at the City Engineers building.
Description
Simply put, living walls are vertical gardens. Basic systems utilise wall creepers or trellis systems with suitable hanging plants, creepers etc. More complex systems utilise specialized and engineered envelope systems where vegetation is planted, irrigated and grown in modular elements which are secured to, or integrated with, a building wall. In these systems, plants typically grow without soil between layers of fibrous material, or in pre-vegetated panels, that are suspended in front of a building wall. They are not planted in the ground or in planter boxes. Based on the principles of hydroponics, water, with added nutrients, drips slowly to the bottom of the wall where any excess is pumped up and re-circulated.

Applications
Since the benefits of living walls are particularly beneficial to urban environments they are most applicable to urban buildings. The living wall can be a form of urban agriculture and are often installed indoors to improve indoor air quality.
### Pros
- Improved energy efficiency.
- Reduced active HVAC requirements.
- Reduces urban heat island effect.
- Improved urban air quality.
- Reduced urban GHG.
- Improved thermal and sound insulation.
- Increased biodiversity.
- Added fire resistance.
- Visually attractive.
- Increased building value.

### Cons
- Additional capex cost; structural strengthening and installation.
- Additional maintenance and associated costs; maintenance access can be difficult unless specific provision has been made in the design.
- Small number of contractors familiar with installation.

---

### 2.1.5.3 Façade example – Solar Shading

#### Description
Solar Shading, whilst occurring in many forms, can be classified into two groups, fixed and operable. Their primary goal is to prevent overheating via exposed fenestration or via excess solar gain in construction materials whilst allowing diffuse natural light into the building. Fixed solar shading devices include roof overhangs, brise soleils, balcony overhangs, fixed vertical fins and fixed louvre devices. Operable solar shading devices, although often similar in appearance to fixed devices, have the added benefit of manual or automatic adjustability enabling a certain amount of building envelope flexibility and potentially increased overall performance.

#### Applications
Buildings with a large amount of north or west facing glazing and where solar gain is a problem *

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* Solar shading is a relatively complex building science, fortunately modern computer software is available to perform solar shading simulations that enable solar shading design optimisation.
Pros

- Improved energy efficiency.
- Reduced active HVAC requirements.
- Lower operating costs.
- Increased building value.
- Low maintenance.
- Long lifespan.
- Reduced GHG emissions associated with fossil fuel energy consumption.

Cons

- Additional capex cost.
- Additional maintenance and associated costs.

---

2.1.5.4 Natural lighting example – Light Shelves

Description
Light shelves are architectural elements that allow daylight to penetrate deep into a building. A horizontal light-reflecting overhang is placed above eye-level and has a high-reflectance upper surface, this surface is then used to reflect daylight onto the ceiling and deeper into a building space. Using advanced technology light can penetrate as much as 4 times the distance between the floor and the top of the window.

Applications
In buildings with deep plans to increase the penetration of natural lighting. They can be used on either side of the façade depending on the design and can be retrofitted in certain instances.

---

Pros

- Improved energy efficiency; reduce the amount of artificial light required.
- Lower operating costs.
- Improved occupant comfort and productivity; light shelves have been found to improve occupant comfort and productivity in classrooms and offices.
- Increased building value.
- Low maintenance.
- Long lifespan.
- Reduced GHG emissions associated with fossil fuel energy consumption.

Cons

- Additional capex cost.
- Additional maintenance and associated costs.
- Not suitable for all buildings due to associated heat gain.
- Often require higher than average floor to ceiling heights.
2.1.5.5 Natural lighting example – Prismatic Skylights

Capex cost
R10 – R15 per m² of floor space.

Savings
60-80% energy saving for lighting systems in buildings where the roof is directly above the workplace and operational hours coincide with daylight hours.

Description
Prismatic skylights are placed in the roof so as to enable diffuse daylight to enter the building. Prismatic skylight systems are typically designed to replace all electric lighting for an average of 68% of the year’s daylight hours in industrial, commercial and educational environments, where the roof is directly above the workplace. Prismatic skylights enable even sunlight dispersion, extremely high CRI value and no undesirable hot spots.

Typical applications
- Retail stores: 800-1000 lux.
- Warehouses: 200-300 lux.
- Factories: 300-600 lux.
- Schools: 40-600 lux.

Pros
- Improved energy efficiency; zero power required for operation.
- Lower operating costs.
- High CRI value.
- Even light dispersion.
- Increased building value.
- Low maintenance.
- Long lifespan; 20-30 yrs.
- Reduced GHG emissions associated with fossil fuel energy consumption.

Cons
- Additional capex cost.
- Retrofit installations require good planning.
- Requires no ceiling.
2.1.5.6 Natural ventilation example – Solar Chimneys

Description
Solar chimneys consist of an uninterrupted vertical flue or ventilation shaft that when heated by the sun create an updraft of warm air that exits from the top of the shaft, cool air is drawn in simultaneously at ground level through windows or ducts in the building envelope. Being able to seal the chimney at night during the cooler winter months will regulate heat loss in the building. The location, orientation, height, cross section and thermal properties of the chimney are crucial for harnessing, retaining and utilizing solar gains. The ventilation shaft is a pronounced vertical element that needs to be higher than the roof level. The solar collector area is typically orientated north and glazed or painted a dark colour to maximise solar heat absorption. The size and shape of the inlet and outlet apertures is also significant, as the principle sees hot air rising and exiting from the shaft causing air from adjacent spaces to flow into the vacuum created.

Applications
Buildings in sunny warm environments where the concept of displacement ventilation and the effect of air moving across occupancy zones is paramount in achieving thermal comfort. Solar chimneys are often designed so as to serve a double function as an atrium and vice versa.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved energy efficiency.</td>
<td>Additional capex cost.</td>
</tr>
<tr>
<td>Reduced reliance on wind driven ventilation.</td>
<td>Additional maintenance and associated costs.</td>
</tr>
<tr>
<td>Improved control of natural air flow.</td>
<td>Require direct sunlight to operate efficiently; in built-up urban areas shading of the site by other buildings can provide challenges.</td>
</tr>
<tr>
<td>Greater choice of natural air intake.</td>
<td>Require custom analysis and design.</td>
</tr>
<tr>
<td>Reduced active HVAC requirements.</td>
<td></td>
</tr>
<tr>
<td>Lower operating costs.</td>
<td></td>
</tr>
<tr>
<td>Increased building value.</td>
<td></td>
</tr>
<tr>
<td>Low maintenance.</td>
<td></td>
</tr>
<tr>
<td>Long lifespan.</td>
<td></td>
</tr>
<tr>
<td>Reduced GHG emissions associated with fossil fuel energy consumption.</td>
<td></td>
</tr>
</tbody>
</table>
2.2 Materials and Green Construction

It is important to understand this section of the document before commencing on the conceptual design stage of a project as it could significantly affect decisions relating to design and construction.

2.2.1 Embodied Energy and Greenhouse Gas (GHG)

Embodied energy is the upstream component of the lifecycle impact of a material and is calculated by summing all the energy consumed by the processes required to produce the product. Typically, these include the energy associated with mining, agriculture and transport.

Note, embodied energy does not include the energy associated with the operation of the building and disposal of the material.

Greenhouse gases (GHGs) are one of the by-products of fossil fuel use and they affect global warming with varying intensities. The intensity of each GHG is measured by its Global Warming Potential (GWP). Carbon dioxide (CO$_2$) is a major GHG which is why it is commonly used as the unit for all GHGs (CO$_2$-equivalent).

Two major contributors to embodied energy in materials are electricity and transport.

For every kilowatt-hour (kWh) of Eskom generated electricity required to produce a material, 0.96 kg of GHG was emitted.

For every kilometre driven by the heavy-duty diesel vehicles required in the manufacture and transport associated with the materials, 0.8 kg of GHG was emitted. When we consider the kilowatt-hours consumed and kilometres driven in the process of manufacturing and transporting each material, the associated GHGs escalates dramatically.

The information in the table below on embodied energy and GHG for common building materials has been collated from several reliable sources, both local and international. Not all the values are absolutely accurate for materials in Kwazulu-Natal, however they are sufficient to act as guidelines as to which materials are more energy intensive than others.

<table>
<thead>
<tr>
<th>Material</th>
<th>Embodied energy (kWh/kg)</th>
<th>Embodied GHG (kgCO$_2$-eq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>~ 1.6</td>
<td>~ 1.5</td>
</tr>
<tr>
<td>Fibre cement</td>
<td>~ 1.3</td>
<td>~ 1.2</td>
</tr>
<tr>
<td>In situ concrete</td>
<td>~ 0.5</td>
<td>~ 0.5</td>
</tr>
<tr>
<td>Precast steam-cured concrete</td>
<td>~ 0.6</td>
<td>~ 0.6</td>
</tr>
<tr>
<td>Precast tilt-up concrete</td>
<td>~ 0.5</td>
<td>~ 0.5</td>
</tr>
<tr>
<td>Concrete blocks</td>
<td>~ 0.4</td>
<td>~ 0.4</td>
</tr>
<tr>
<td>Galvanised steel</td>
<td>~ 10.6</td>
<td>~ 10.2</td>
</tr>
<tr>
<td>Copper</td>
<td>~ 27.8</td>
<td>~ 26.7</td>
</tr>
<tr>
<td>Aluminium</td>
<td>~ 47.2</td>
<td>~ 45.3</td>
</tr>
<tr>
<td>Glass</td>
<td>~ 3.5</td>
<td>~ 3.4</td>
</tr>
<tr>
<td>Clay bricks</td>
<td>~ 0.7</td>
<td>~ 0.7</td>
</tr>
<tr>
<td>AAC</td>
<td>~ 1.0</td>
<td>~ 1.0</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>~ 1.2</td>
<td>~ 1.2</td>
</tr>
<tr>
<td>Gypsum plaster</td>
<td>~ 2.9</td>
<td>~ 2.8</td>
</tr>
</tbody>
</table>
A thorough understanding of the thermal properties of construction materials is a key requirement for energy efficient design as they will dictate how a building responds to fluctuations in temperature.

South Africa is exposed to high levels of solar radiation which enters directly through transparent windows heating up the internal space. Simultaneously, solar radiation heats the building envelope which, over time, conducts and radiates heat into the internal space; the combined effect is termed Solar Gain. In addition to solar shading devices, spectrally selective building envelope coatings and radiant barriers, the rate at which heat is transferred through the building envelope into the internal space, or vice versa, is dependent on the thermal properties of the building’s construction materials.

### 2.2.2 Thermal Insulation and Related Properties of Materials

A thorough understanding of the thermal properties of construction materials is a key requirement for energy efficient design as they will dictate how a building responds to fluctuations in temperature.

South Africa is exposed to high levels of solar radiation which enters directly through transparent windows heating up the internal space. Simultaneously, solar radiation heats the building envelope which, over time, conducts and radiates heat into the internal space; the combined effect is termed Solar Gain. In addition to solar shading devices, spectrally selective building envelope coatings and radiant barriers, the rate at which heat is transferred through the building envelope into the internal space, or vice versa, is dependent on the thermal properties of the building’s construction materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Embodied energy (kWh/kg)</th>
<th>Embodied GHG (kgCO₂eq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite</td>
<td>~ 0.8</td>
<td>~ 0.8</td>
</tr>
<tr>
<td>Stabilised earth</td>
<td>~ 0.2</td>
<td>~ 0.2</td>
</tr>
<tr>
<td>Kiln dried sawn softwood</td>
<td>~ 0.9</td>
<td>~ 0.9</td>
</tr>
<tr>
<td>Kiln dried sawn hardwood</td>
<td>~ 0.6</td>
<td>~ 0.6</td>
</tr>
<tr>
<td>Air dried sawn hardwood</td>
<td>~ 0.1</td>
<td>~ 0.1</td>
</tr>
<tr>
<td>Hardboard</td>
<td>~ 6.7</td>
<td>~ 6.4</td>
</tr>
<tr>
<td>Particleboard</td>
<td>~ 2.2</td>
<td>~ 2.1</td>
</tr>
<tr>
<td>MDF</td>
<td>~ 3.1</td>
<td>~ 3.0</td>
</tr>
<tr>
<td>Plywood</td>
<td>~ 2.9</td>
<td>~ 2.8</td>
</tr>
<tr>
<td>Glue-laminated timber</td>
<td>~ 3.1</td>
<td>~ 3.0</td>
</tr>
<tr>
<td>Laminated veneer lumber</td>
<td>~ 3.1</td>
<td>~ 3.0</td>
</tr>
<tr>
<td>Plastics</td>
<td>~ 25.0</td>
<td>~ 24.0</td>
</tr>
<tr>
<td>PVC</td>
<td>~ 25.0</td>
<td>~ 24.0</td>
</tr>
<tr>
<td>Synthetic rubber</td>
<td>~ 30.6</td>
<td>~ 29.4</td>
</tr>
<tr>
<td>Acrylic paint</td>
<td>~ 17.1</td>
<td>~ 16.4</td>
</tr>
</tbody>
</table>

**Figure 45: Insulation Options In a Building (courtesy of TIASA)**
The ability of a material to conduct heat is determined by its thermal conductivity (k) value; the SI unit for which is Watts per metre per Kelvin (W.m\(^{-1}\).K\(^{-1}\)).

The higher a material's thermal conductivity value, the faster the rate of heat transfer through that material.

In terms of insulation, the higher the thermal conductivity of a material the thicker it has to be in order to match the insulative properties of materials with lower conductivity values.

The basic formula to calculate the rate of heat transfer through a single material is:

\[
\text{Rate (W)} = \text{thermal conductivity value (W.m}^{-1}\text{.K}^{-1}) \times \text{Area (m}^2\text{)} \times \text{difference in temperature (K)}
\]

The R-value of a material, or product, is a measurement of how effectively it resists the transfer of heat via conduction; the higher the R-value, the slower the heat transfer through the material.

Air has a high R-value which is why its use between and surrounding layers of an object is so effective at increasing the object’s overall R-value.

For instance, the R-value of a single-pane glass window is very low but is more than doubled when adding a second pane of glass and sealing the air between the panes.

\[
R = \frac{\text{thickness (m)}}{\text{thermal conductivity value \left(\frac{W}{m \times K}\right) \times Area (m^2)}}
\]

To calculate the R-value of a composite object or material you simply add up the individual R-values of each material making up the thickness through which the heat transfer rate is required.

\[
R_{\text{Total}} = R_1 + R_2 + R_3 + \ldots + R_n
\]

The U-value of a material, or product, is a measurement of how effectively transfers heat via conduction, making it the inverse of R-Value for unit area; the higher the U-value, the faster the heat transfer through the material.

\[
U = \frac{1}{R - \text{Value} \left(\frac{W}{K}\right)}
\]
### Table 5: Thermal conductivity and R-values for common building materials

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value for item</th>
<th>Thermal conductivity (k) (W.m(^{-1}).K(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>General materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry sand</td>
<td>-</td>
<td>0.150 - 0.250</td>
</tr>
<tr>
<td>Dry earth</td>
<td>-</td>
<td>1.500</td>
</tr>
<tr>
<td>Sandstone</td>
<td>-</td>
<td>1.730</td>
</tr>
<tr>
<td>Slate</td>
<td>-</td>
<td>2.000</td>
</tr>
<tr>
<td>Marble</td>
<td>-</td>
<td>2.080 - 2.940</td>
</tr>
<tr>
<td>Granite</td>
<td>-</td>
<td>1.700 - 4.000</td>
</tr>
<tr>
<td>Compressed straw</td>
<td>-</td>
<td>0.090</td>
</tr>
<tr>
<td>Dense brick</td>
<td>-</td>
<td>1.310 - 1.410</td>
</tr>
<tr>
<td>Plywood</td>
<td>-</td>
<td>0.130</td>
</tr>
<tr>
<td>Particle Board - High Density</td>
<td>-</td>
<td>0.170</td>
</tr>
<tr>
<td>Particle Board - Medium Density</td>
<td>-</td>
<td>0.140</td>
</tr>
<tr>
<td>Particle Board - Low Density</td>
<td>-</td>
<td>0.078</td>
</tr>
<tr>
<td>Hardwood across the grain (Oak)</td>
<td>-</td>
<td>0.160</td>
</tr>
<tr>
<td>Cork</td>
<td>-</td>
<td>0.044</td>
</tr>
<tr>
<td>Softwood across the grain (Pine)</td>
<td>-</td>
<td>0.120</td>
</tr>
<tr>
<td>Rubber</td>
<td>-</td>
<td>0.150</td>
</tr>
<tr>
<td>Gypsum</td>
<td>-</td>
<td>0.170</td>
</tr>
<tr>
<td>Cement Mortar</td>
<td>-</td>
<td>0.720</td>
</tr>
<tr>
<td>Cinder aggregate</td>
<td>-</td>
<td>0.670</td>
</tr>
<tr>
<td>Concrete</td>
<td>-</td>
<td>1.700</td>
</tr>
<tr>
<td>Stucco</td>
<td>-</td>
<td>0.180</td>
</tr>
<tr>
<td>Glass</td>
<td>-</td>
<td>1.050</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>-</td>
<td>16.000</td>
</tr>
<tr>
<td>Aluminium</td>
<td>-</td>
<td>250.000</td>
</tr>
<tr>
<td>Copper</td>
<td>-</td>
<td>401.000</td>
</tr>
<tr>
<td>Mica</td>
<td>-</td>
<td>0.710</td>
</tr>
<tr>
<td>Iron</td>
<td>-</td>
<td>80.000</td>
</tr>
<tr>
<td>Tin</td>
<td>-</td>
<td>67.000</td>
</tr>
<tr>
<td>Zink</td>
<td>-</td>
<td>116.000</td>
</tr>
<tr>
<td>Bricks and blocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face brick</td>
<td>-</td>
<td>1.300</td>
</tr>
<tr>
<td>Common brick</td>
<td>-</td>
<td>0.720</td>
</tr>
<tr>
<td>Concrete Block - Normal wt. 8'' empty core</td>
<td>1.04</td>
<td>-</td>
</tr>
<tr>
<td>Concrete Block - Normal wt. 12'' empty core</td>
<td>1.23</td>
<td>-</td>
</tr>
<tr>
<td>Material</td>
<td>R-value for item</td>
<td>Thermal conductivity (k) (W.m⁻¹.K⁻¹)</td>
</tr>
<tr>
<td>----------</td>
<td>------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Concrete Block - Medium wt. 8” empty core</td>
<td>1.50</td>
<td>-</td>
</tr>
<tr>
<td>Concrete Block - Light wt. 8” empty core</td>
<td>2.55</td>
<td>-</td>
</tr>
<tr>
<td>Concrete Block - Light wt. 12” empty core</td>
<td>2.45</td>
<td>-</td>
</tr>
</tbody>
</table>

**Roof specific**

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value for item</th>
<th>Thermal conductivity (k) (W.m⁻¹.K⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt shingle</td>
<td>-</td>
<td>0.750</td>
</tr>
<tr>
<td>Clay tile</td>
<td>-</td>
<td>0.690</td>
</tr>
<tr>
<td>Thatch</td>
<td>-</td>
<td>0.070</td>
</tr>
<tr>
<td>Corrugated iron</td>
<td>-</td>
<td>60.0 - 80.0</td>
</tr>
</tbody>
</table>

**Insulation specific**

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value for item</th>
<th>Thermal conductivity (k) (W.m⁻¹.K⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>-</td>
<td>0.025</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>-</td>
<td>0.058</td>
</tr>
<tr>
<td>Cellulose Fibre Loose-Fill (27.5kg/m³)</td>
<td>-</td>
<td>0.040 (100)</td>
</tr>
<tr>
<td>Flexible Fibre Glass Blanket (10-18 kg/m³)</td>
<td>-</td>
<td>0.040 (100)</td>
</tr>
<tr>
<td>Flexible BOQ Polyester Fibre Blanket (24 kg/m³)</td>
<td>-</td>
<td>0.038 (90)</td>
</tr>
<tr>
<td>Flexible Polyester Blanket (11.5 kg/m³)</td>
<td>-</td>
<td>0.046 (110)</td>
</tr>
<tr>
<td>Flexible Mineral/Rockwool (60-120 kg/m³)</td>
<td>-</td>
<td>0.033 (80)</td>
</tr>
<tr>
<td>Flexible Ceramic Fibre (84 kg/m3)</td>
<td>-</td>
<td>0.033 (80)</td>
</tr>
<tr>
<td>* Rigid Expanded Polystyrene (EPS)SD (15 kg/m³)</td>
<td>-</td>
<td>0.035 (80)</td>
</tr>
<tr>
<td>* Rigid Extruded Polystyrene (XPS) (32 kg/m³)</td>
<td>-</td>
<td>0.028 (65)</td>
</tr>
<tr>
<td>Rigid Fibre Glass Board (47.5 kg/m³)</td>
<td>-</td>
<td>0.033 (80)</td>
</tr>
<tr>
<td>Rigid BOQ Polyester Fibre Board (61 kg/m³)</td>
<td>-</td>
<td>0.034 (80)</td>
</tr>
<tr>
<td>* Rigid Polyurethane Board (32 kg/m³)</td>
<td>-</td>
<td>0.025 (60)</td>
</tr>
</tbody>
</table>

* Thermal efficiencies are dependant on materials thickness, density, age, operating temperature and moisture. Values in brackets are the minimum recommended thicknesses in mm for KZN coastal roof insulation.

**Fenestration specific**

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value for item</th>
<th>Thermal conductivity (k) (W.m⁻¹.K⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single pane (standard)</td>
<td>0.90</td>
<td>-</td>
</tr>
<tr>
<td>Single pane (low emissivity)</td>
<td>1.10</td>
<td>-</td>
</tr>
<tr>
<td>Single pane w/storm window</td>
<td>2.00</td>
<td>-</td>
</tr>
<tr>
<td>Double pane, 6mm air space</td>
<td>1.70</td>
<td>-</td>
</tr>
<tr>
<td>Double pane, 12mm air space</td>
<td>2.00</td>
<td>-</td>
</tr>
<tr>
<td>Double pane, 12mm air space (low emissivity)</td>
<td>2.99</td>
<td>-</td>
</tr>
<tr>
<td>Triple pane, 6mm air space</td>
<td>2.60</td>
<td>-</td>
</tr>
</tbody>
</table>

**Floor specific**

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value for item</th>
<th>Thermal conductivity (k) (W.m⁻¹.K⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete slab with no insulation</td>
<td>11</td>
<td>-</td>
</tr>
<tr>
<td>Concrete slab with 25mm polystyrene perimeter insulation</td>
<td>46</td>
<td>-</td>
</tr>
<tr>
<td>Concrete slab with 50mm polystyrene perimeter insulation</td>
<td>65</td>
<td>-</td>
</tr>
</tbody>
</table>
Every decision you make about the materials you use either leads toward a more sustainable future or decreases the opportunities for future generations to live lifestyles that we have come to take for granted.”
David Johnstone; Green Builder and Sustainability Consultant

The following section includes a few examples of innovative building systems that utilise low embodied energy materials to good effect. When applying to build with a non-standardised system, a building owner/developer/representative must apply for a single case permission whereby, prior to construction, building plans must be approved by the local authority applying the National Building regulations (NBRs). Application for compliance with the NBRs may be demonstrated by:

- Meeting the relevant deemed-to-satisfy rules of the current South African Bureau of Standards (SABS) Code of Practise 0400: The Application of the National Building Regulations, when using a conventional method of construction, or
- Supplying a valid Agrement certificate, when using a non-standardised or innovative building system.
- Submitting a rational design* produced by a competent person as defined under the Engineering Profession of South Africa Act, Act 114 of 1990.

In critical applications and for public works, products and systems used will require formal approval. However, in other instances public authorities may be less concerned about compliance than the owners, developers, consumers, building professionals and financiers.

This may require testing of materials and construction systems by SABS and/or Agrement SA; both organisations are largely complementary, SABS deals with standards and codes of practise which relate to conventional products whilst Agrement SA assesses innovative, non-standardised construction materials, products and systems. Both SABS and Agrement SA maintain links with other internationally recognised technical assessments organisations, meaning that it is possible to use results from tests conducted in other countries so long as the tests are done in accordance with international standards.

Note, the following examples are not at all intended as the list from which to choose an innovative building system. The purpose of their inclusion is to illustrate that there are innovative building systems available in South Africa that are as good, if not better overall, than conventional methods. The list of examples included is:

- Structural Insulated Panels (SIP)
- Straw bale construction
- Cob/Adobe construction
- Rammed Earth Construction
- Sandbag construction

* Rational design: any design involving a process of reasoning and calculation that is based on the consistent application of appropriate national or international standards, and engineering codes or other relevant, authoritative and published technical literature.

# Agrément SA is an independent organisation established by the Minister of Public Works and housed at the CSIR. Their primary business focus is the certification of non-standardised or innovative building products through technical assessments that verify whether the products and systems are fit for purpose.
### 2.2.3.1 Structural Insulated Panels (SIPs)

**Cost**
R6 000-R8 000 per m² depending on finishes. Although, the finished cost of an SIP structure is comparable to brick building the real savings are realised on the reduced heating and cooling operational costs.

**Description**
The use of SIPs has been increasing rapidly over the last 50 years in Europe and the United States largely due to their combination of good insulative characteristics, ease and speed of construction as well as cost.

SIPs are pre-engineered building systems consisting of an inner rigid insulating core and outer skins of fibre board. In many instances drywall, or other alternative, is laminated as an additional layer to the fibreboard during manufacture. When correctly designed and assembled, a building constructed from SIP has no need for an additional framework to be built.

SIPs are used extensively in the USA and typically pass every standard fire test required of wood based construction in the USA.

There are suppliers of SIPs in South Africa that have had their products passed by SABS and ISO standards.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Energy efficient; the insulative core provides good thermal and sound insulative properties.</td>
<td>● The synthetic insulation material, generally used in SIPs, is not environmentally friendly.</td>
</tr>
<tr>
<td>● Buildings can be rapidly erected.</td>
<td></td>
</tr>
<tr>
<td>● Competitively priced.</td>
<td></td>
</tr>
</tbody>
</table>

### 2.2.3.2 Straw Bale

**Cost**
R6 000-R8 000 per m² depending on finishes. Although, the finished cost of a straw bale structure is comparable to brick building the real savings are realised on the reduced heating and cooling operational costs.

**Description**
Straw bales are made from grain stalks differing from hay bales which are made from grasses. Straw bale construction can be either load bearing or non-load bearing. Load bearing straw bale walls have a wooden top plate “capping” the wall.
structure. The top plate, which is secured to the foundation, acts as a mounting plate for the roof structure and spreads the load of the roof structure evenly over the wall length. Non-load bearing straw bale will typically have a post-and-beam frame as support construction with the straw bales providing only insulation; this method is also called the “in-fill method”.

Applications
Straw bale technology sees most favourable benefits in dry hot climates, cold climates and temperate climates with hot and cold seasonal swings. The technology has been applied to homes, farm buildings, schools, commercial buildings, churches, community centres, government buildings, airplane hangars, well houses and more.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Energy efficient; the technology will limit the amount of heat gain and heat loss and should be used in conjunction with roof insulation, glass films and airtight construction.</td>
<td>● Straw bale walls are susceptible to moulding and deterioration if they are not well protected from moisture.</td>
</tr>
<tr>
<td>● Straw bale construction is the effective use of a waste product derived from cereal growers. In many parts of our country it is burned, creating pollution.</td>
<td>● Straw is not readily available in KwaZulu Natal, requiring transportation from other provinces such as the Western Cape and Orange Free State.</td>
</tr>
<tr>
<td>● The relatively inexpensive straw bales, if bought at the time of harvest and proximity does not necessitate extensive transport, are a financially attractive building block.</td>
<td></td>
</tr>
</tbody>
</table>

2.2.3.3 Cob /Adobe Cost

Cost
R6 000-R8 000 per m² depending on finishes. Although, the finished cost of a cob/adobe structure is comparable to brick building the real savings are realised on the reduced heating and cooling operational costs.

Description
Cob and Adobe building technologies both utilise a mixture of clay, coarse sand, fine sand, silt, and water. Both techniques build up layers of wall on a protruding foundation, ideally stone, which acts as a ‘Damp Proof Course’ to help prevent the base of the wall from absorbing moisture from the ground. Cob building is a process of laying the straw-clay mixture in layers above the foundation, tapering in as one builds up, and allowing each layer to dry before laying the next. Adobe is made into brick shapes using forms, which are then removed to allow the bricks to bake in the sun. Further clay-soil-water mix is used as mortar between the adobe bricks. Both technologies usually use local material and are thus some of the most affordable building technologies.
Applications
Typical application areas would be temperate climates with hot and cold seasonal swings, cold climates and hot dry climates which would fully utilise the thick thermal mass for heat storage in winter, and for cooling during the summer. Cob and adobe buildings are typically used for homes and small-to-medium sized commercial buildings.

Pros

- High thermal mass that can be extremely energy efficient in most climates.
- Greatly reduced carbon footprint with little impact on the environment.
- Ideal technologies for owner builders.
- Relatively inexpensive for a long lasting building.
- Both building techniques lend themselves to free-form, fire proof walls.

Cons

- Fairly labour intensive
- Obtaining approval from the local building department can be problematic, although as ‘infill’ is usually approved.
- Adobe bricks and Cob walls cannot be laid during wet or freezing weather.
- Insects and small rodents can burrow into the walls weakening them; the use of plaster reduces this problem.

2.2.3.4 Rammed Earth

Cost
R7 000-R9 000 per m² depending on finishes. Although, the finished cost of a rammed earth structure is comparable to brick building the real savings are realised on the reduced heating and cooling operational costs.

Description
Rammed earth construction requires a damp mixture of sand, gravel and clay which is compacted with a manual or pneumatic tamper machine into an externally supported frame. The final result is a sculpted wall of exceptional strength and high thermal mass. A stabiliser can be added to the earthen mixture, usually lime or cement. However, when cement is added as a binder, even in a range of 5-13%, a rammed earth wall of 300mm in section will have more cement than a 115mm concrete building block wall and is not considered very environmentally friendly.
Cost
R6 000-R8 000 per m² depending on finishes. Although, the finished cost of a sandbag structure is comparable to brick building the real savings are realised on the reduced heating and cooling operational costs.

Applications
The applications of this technology are vast since the technology lends itself to being structurally sound whilst providing an aesthetically pleasing finish that requires minimal maintenance. The earthen walls do exhibit an ability to regulate the humidity of the interior to between 40% and 60% which are excellent conditions for storing books and similar products and happen to be the upper and lower trigger points for asthma sufferers.

Pros
- Greatly reduced carbon footprint with little impact on the environment when using an environmentally friendly stabiliser.
- High thermal mass that can be extremely energy efficient in most climates.
- Extremely strong and fire proof.
- Low maintenance.
- Insects and rodents do not pose any problems to this type of wall.

Cons
- Rammed earth walls are labour intensive.
- Analysis of soil mixture is crucial.

2.2.3.5 Sandbag/Ecobeam

Description
Sandbag construction is normally achieved through the “in-fill” method around a pillar and beam construction. Lightweight bags are filled with sand or other earth mixes, on site, and placed layer upon layer within the frame to create a substrate for plaster. The technology has developed in South Africa to a point where pillar and beams are built on site, allowing for minimal transport of compact loads, along with the empty sandbags. Buildings not using pillar and beam construction will usually have curved walls for added shear strength, integrated dome-type roofs and strips of barbed wire between layers of the sandbags to add tensile strength. The bags are wet just before plastering which allows the plaster to cure with a stronger bond to the walls.
**Applications**

Typical application areas would be temperate climates with hot and cold seasonal swings, cold climates and hot dry climates which would fully utilise the thick thermal mass for heat storage in winter, and for cooling during the summer. Sandbag/Ecobeam construction is used for homes and as infill for large commercial projects.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmentally friendly; minimal transport necessary; subsoil for bag filling is usually found onsite, minimal energy used during construction, final product can be reused or recycled.</td>
<td>Labour intensive technology</td>
</tr>
<tr>
<td>Strong structures are erected quickly using only sandbags as walls and integrated roof structures at relatively little expense.</td>
<td>Care must be taken to prevent water penetrating through to the sandbags.</td>
</tr>
<tr>
<td>Economical pillar and beam technology can be integrated for more conventional looking buildings at a slightly increased expense.</td>
<td>Plastic bags are not environmentally friendly.</td>
</tr>
<tr>
<td>Minimal water needed for construction, water is used during plastering of the final product.</td>
<td></td>
</tr>
<tr>
<td>The technology exhibits good thermal mass for regulating internal temperatures.</td>
<td></td>
</tr>
<tr>
<td>Services can easily be added during the construction phase.</td>
<td></td>
</tr>
</tbody>
</table>
In addition, please take note of the following eThekwini Municipality bylaws:

1. “No person shall install or permit to be installed a new electrical installation in any premises within the area of supply and connect any such installation to the Council’s supply main, except under the authority of the written permission of the Engineer, which authority the Engineer may grant, subject to such conditions as he may determine, or refuse;” eThekwini Municipality Electricity Supply Bylaws, pg 33, New Electrical Installations

2. “Before making any alteration or addition to any electrical installation installed within the area of the supply that requires an increase in electricity supply capacity, or an alteration to the service, the electrical contractor shall give notice to the Engineer of his intentions in accordance with the Electrical Installation Regulations.” eThekwini Municipality Electricity Supply Bylaws, pg 35, Notice of Intention to alter or add to Existing Electrical Installations

3.1. Power Supply

<table>
<thead>
<tr>
<th>Application</th>
<th>Home</th>
<th>Hotel</th>
<th>Restaurant</th>
<th>Office</th>
<th>Retail</th>
<th>School</th>
<th>Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LPG</td>
<td>***</td>
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</tr>
<tr>
<td>Biodiesel</td>
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<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Cogen. &amp; Trigen. plants</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
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<tr>
<td>Fuel Cells</td>
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<td>•</td>
<td>•</td>
</tr>
<tr>
<td>UPS</td>
<td>•</td>
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<td>•</td>
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<tr>
<td>Biogas Digesters</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
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<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Photovoltaic Systems</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
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<tr>
<td>Wind Turbine Systems</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

Key: Unlikely to be applicable
Possibly applicable
Likely to be applicable
Highly applicable

* Engineer; the Executive Director of the Durban Electricity Service Unit, or his duly authorised representative.
Globally, use of grid connected renewable energy is on the rise, actually it is the fastest growing sector of the energy market.

The South African Government has set a renewable energy generation target of 10 000 GWh per year by the year 2013. The aim of the South African Renewable Energy Feed-in Tariffs (REFIT’s) is to encourage the development of renewable energy generation in South Africa by setting technology specific tariffs that are envisaged to generate a fair degree of profit for the respective independent power producers (IPPs).

Under the current format Eskom is obliged to purchase energy from IPPs that qualify for REFIT at above market rates. The South African REFIT’s are still in their infancy and at the time of writing only the tariffs of phase 1 are available, see table below.

### Table 7: Renewable Energy Feed-in Tariffs 2009, Phase 1

<table>
<thead>
<tr>
<th>Technology</th>
<th>REFIT (R/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>1.25</td>
</tr>
<tr>
<td>Hydro</td>
<td>0.94</td>
</tr>
<tr>
<td>Landfill gas</td>
<td>0.90</td>
</tr>
<tr>
<td>Concentrating Solar</td>
<td>2.10</td>
</tr>
</tbody>
</table>

The proposed tariffs for Phase 2 of the REFIT are listed in the table below; the final decision on these technologies is likely to be available by the end of 2009.

### Table 8: Proposed Renewable Energy Feed-in Tariffs 2009, Phase 2

<table>
<thead>
<tr>
<th>Technology</th>
<th>REFIT (R/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrating Solar Power (CSP) trough without storage</td>
<td>3.132</td>
</tr>
<tr>
<td>Concentrating Solar Power (CSP) tower with 6 hours of storage per day</td>
<td>2.308</td>
</tr>
<tr>
<td>Ground or building mounted photovoltaics (&gt;1MW)</td>
<td>4.488</td>
</tr>
<tr>
<td>Concentrating photovoltaics (PV) without storage</td>
<td>5.481</td>
</tr>
<tr>
<td>Biomass (solid fuel)</td>
<td>1.181</td>
</tr>
<tr>
<td>Biogas</td>
<td>0.962</td>
</tr>
</tbody>
</table>

The size required in order to qualify for REFIT varies for the different technologies. However, at this stage, in order for any project to prove feasible it will likely need to have a peak generation capacity of not less than 1 megawatt (MW). Although this is not a large amount when compared to the generation capacity of a typical coal power plant (~3500 MW) it is still significantly larger than that of the similar small systems installed in residential homes (0.2-3 kW).

See NERSA’s website for further information: www.nersa.org.za
3.1.2 Natural Gas

Capex cost
Gas is currently an unregulated fuel in South Africa and it is fair to say that until the price becomes regulated the price will vary from client-to-client according to their alternative which in the case of natural gas is typically electricity, oil and coal.

Generally, the price range for gas alone, excluding infrastructure, is:
- R0.58–R0.71 per kWh
- R161.25–R197.00 per GJ
Natural gas combustion efficiencies range between 65-90%, therefore the current practical cost is R0.64 – R1.08 per kWh.

Savings
The price of natural gas is generally competitive with alternatives such as electricity, oil and coal. Therefore, it is unlikely that there will be savings however additional influential factors, mentioned below, frequently results in the implementation of the technology.

Description
Natural gas is composed primarily of methane. In its refined form it is the cleanest burning of all fossil fuels; the main products of its combustion are carbon dioxide and water vapour. However, natural gas is refined prior to distribution and in South Africa it is also synthesised from coal. The refineries responsible for this process release vast amounts of greenhouse gas and other atmospheric pollutants that have been known to cause respiratory illnesses, skin irritations, nausea, eye problems, headaches, birth defects, leukemia and others.

The typical primary benefits of using natural gas are the ability to rapidly regulate the amount of heat produced and its availability as a piped gas. In Kwazulu-Natal, Sasol Gas and Spring Lights Gas are currently the only suppliers of natural gas.

Typical applications
Gas is used for a wide range of applications, including:
- Spatial and water heating,
- Cooking,
- Backup generator & absorption chiller fuel,
- Heat treatment, glass manufacturing, tiles and powder coating.

Pros
- Ability to rapidly regulate the amount of heat generated.
- Relatively clean burning fuel; fairly low emissions when compared to other hydro-carbon fuels.
- Potentially lower operating costs.
- It is a piped gas and thus fairly constantly available.

Cons
- Manufacturing process is responsible for a significant amount of pollutants.
- Colourless and denser than air, making leaks difficult to detect and dangerous.
- Gas supply limited to pipeline network.
3.1.3 Liquefied Petroleum Gas (LPG)

**Capex cost**
Gas is currently an unregulated fuel in South Africa and it is fair to say that until the price becomes regulated the price will vary according to the alternative which in the case of LPG is typically electricity, oil and coal.

At the time of writing the price range for LP gas is:

- R0.83 – R0.95 per kWh
- R10.90 - R12.53 per kg

**Savings**
LP gas combustion efficiencies for cookers and heaters range between 75-90%; therefore the current practical cost is R0.92 – R1.27 per kWh. This price is currently higher than the cost of electricity, therefore it is unlikely that there will be savings however additional influential factors, mentioned below, frequently results in the implementation of the technology.

**Description**
Liquid petroleum gas (LPG) is composed primarily of propane and butane.
At the final point of use it is a clean burning fuel; per kWh emitting 19% less carbon dioxide than oil, 30% less than coal and more than 50% less than coal-generated electricity distributed via the grid. However, LPG is synthesised by refining fossil fuels such as crude oil, natural gas and coal. The refineries responsible for this process release vast amounts of greenhouse gas and other atmospheric pollutants that have been known to cause respiratory illnesses, skin irritations, nausea, eye problems, headaches, birth defects, leukemia and others.
The typical primary benefits of using LP gas are the ability to rapidly regulate the amount of heat produced and its energy storage capability. LPG is available in varying amounts from retailers across the country.

**Typical applications**
Gas is used for a wide range of applications within buildings, including:
- Spatial heating
- Water heating
- Cooking
- Backup generator & absorption chiller fuel

**Pros**
- Ability to rapidly regulate the amount of heat generated.
- Relatively clean burning fuel.
- Potentially lower operating costs.
- Good storage capability.

**Cons**
- Manufacturing process is responsible for a significant amount of pollutants.
- Colourless and denser than air, making leaks difficult to detect and dangerous.
3.1.4 Biodiesel

**Capex cost**
Biodiesel is currently an unregulated fuel in South Africa and it is fair to say that until the price becomes regulated the price will vary according to the price of petroleum diesel.

At the time of writing the price range for biodiesel is:
- R1.64 – R2.13 per kWh @ 33% generation efficiency
- R5.00 – R6.50 per litre

At the time of writing the price range for petroleum diesel is:
- R1.92 – R2.00 per kWh @ 33% generation efficiency
- R6.32 – R6.60 per litre

**Savings**
- R-0.13 - R0.28 per kWh @ 33% generation efficiency
- R0.10 – R1.32 per litre

**Description**
Biodiesel is a renewable fuel typically produced through the reaction of a vegetable oil or animal fat with methanol/ethanol; glycerine is a by-product of the process. Biodiesel can be used as a replacement for petroleum diesel fuel, however until the industry has matured it would be wise to blend biodiesel with regular diesel. One manufacturer has found that a blend of 5% biodiesel and 95% petroleum diesel by volume has shown improvements in performance, enhanced lubricity and a reduction in emissions. A blend of 20% by volume biodiesel with 80% by volume petroleum diesel, has demonstrated significant environmental benefits with a minimum increase in cost.

It is important to ensure that the production of biofuels does not place strain on the availability and price of critical sources of food. The possibility that land previously used for food production could instead be used for the growth of biofuels crops must not be realised. Therefore, be aware of the source of any biofuels and understand the ramifications of its production.

**Typical applications**
Biodiesel is an acceptable fuel for modern diesel generators; however take note of the following:

- Replace any natural rubber fuel lines on older equipment with synthetic fuel lines as the biodiesel will corrode the rubber fuel lines over time.
- Biodiesel is an effective solvent and should be mixed in, by increasing volume over time, to existing fossil diesel systems to avoid dissolved tars, varnishes and gums created by fossil diesel in your fuel system, suddenly blocking the fuel filters.
- Replace fuel filters soon after switching to biodiesel.
Capex costs
R7 600 – R32 000 per kW capacity

Savings
Potential to increase overall efficiency of useful energy conversion from approximately 30% for electrical generation alone, to 80-90% when utilising the waste heat emitted for heating or cooling.

Description
Cogeneration and trigeneration power plants generate electricity and utilise the waste heat to provide heat directly (cogeneration) and/or cooling indirectly using an absorption chiller (trigeneration). They become economically feasible when the overall cost of their combined outputs (electricity, heat, coolth) is less than that of the alternative, which in urban South African buildings is generally grid connected electricity and electrical HVAC systems.

From an environmental point of view, because they utilise waste heat in addition to electricity, they are approximately 60% more efficient than standard petrol/diesel generators and grid electricity.

Applications
Anywhere there is a large collective requirement for heating and cooling in addition to electricity within a relatively confined area e.g. hospitals, large educational institutions, malls, office parks, industry etc.
Capex costs
R33 600 - R50 000 per kW capacity; excluding the cost of operational gas required.

Savings
The operating cost of fuel cells is reliant on the cost of the gas utilised which is, currently, generally higher than that of grid electricity.

Description
A fuel cell generates electricity through an electrochemical energy conversion process, the process requires a hydrogen rich fuel but there is no combustion process and no hazardous emissions are produced. Currently in South Africa, the typical primary benefit of using fuel cells is their ability to be used as reliable, clean and quiet backup power systems.

Applications
- As back-up to the national electricity grid; where hydrogen is the fuel of choice.
- As a permanent power source; where LPG is preferred due to its lower cost.

3.1.6 Fuel Cells

Pros
- Improved energy efficiency; produces electricity at 50-80% efficiency.
- Recyclable by-products; the by-products of generation are heat and water.
- Zero GHG emissions produced during operation.
- Relatively low maintenance requirements.
- Operate extremely quietly.
- Capability for remote site generation.
- Increased building value.

Cons
- High capex cost.
- Require commissioning.
3.1.7 Uninterrupted Power Supply (UPS) Systems

Capex costs
The overall capex range of a system is the sum of the following:

- R2 000 – R9 500 per kW of installed capacity, plus
- R83– R1 381 per kWh capacity based on a 5 hour discharge rate for a 300 and 2 000 cycle battery bank.

Power factor correction of electrical circuits prior to specifying an appropriate UPS system will enable the use of a system with lesser power capacity (kW) requiring less capital expenditure.

Savings
UPS units store energy obtained from an electrical supply, therefore savings will only be achieved through intelligent time-of-use or through averting downtime loss of revenue and the operational costs of other possible alternative power supplies including petrol and diesel generators.

Description
Essentially, UPS systems consist of a battery bank, inverter, charger and an automatic transfer switch which enables the more or less seamless switch from primary power supply to the UPS system. The load size (kW) that a UPS system can support is dependent on the inverter capacity whilst the length of time they can continuously operate is dependent on the size (Ah) of the battery bank. Typically, the battery bank is charged using power from the primary power supply but can also be charged from a reliable alternative supply e.g. solar. Currently in South Africa, the typical primary benefit of using UPSs is their ability to supply ‘instantaneous’ electrical power in the event of an electrical grid power failure, thus enabling electrical equipment to continue operating.

Applications
They are typically utilised as backup power systems but can also be used to shift electrical load from one period to another.

Pros
- Ability to supply ‘seamless’ power
- Produce negligible onsite emissions but are dependent on an electrical power supply for charging and thus have associated emissions.
- Less expensive to operate than generators of comparable size.
- Low maintenance.
- Increased building value.
- Operate extremely quietly.

Cons
- Relatively high capex cost.
- System batteries have a finite cycle life and must be replaced thereafter; batteries can, and should, be recycled.
### 3.1.8 Biogas Digesters

#### Capex costs
R42 000 – R150 000 per kW capacity.

#### Savings
Although there is an operational cost reduction attributed to the use of waste materials as input fuel as opposed to being sent to waste treatment plants and landfill, due to their high capex cost they currently have a lengthy payback period when compared solely to the cost of grid electricity. However, payback periods can be significantly reduced when additional value is created through supplementary revenue streams associated with the carbon market, energy security and advertising.

In addition, it is likely that a REFIT may be applicable in the near future.

#### Description
Biogas Digesters produce combustible gas from biodegradable organic matter; the gas can be used for similar purposes as LP Gas and Natural Gas. Methanogens within biogas digesters produce combustible biogas from biodegradable organic material, including human faecal matter.

On average, the total energy available in the biogas derived from human faecal matter is 150 kJ or 42 Watt hours per day, per human.

In order to operate at peak efficiency, biogas digesters require a fairly constant amount of input material, water-to-solids ratio and carbon-to-nitrogen ratio.

#### Applications
Locations with a large amount of free organic waste and a gas requirement.

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#### Pros
- Renewable energy. Ability to harvest energy from waste products.
- Reduced waste material sent to landfill and waste processing plants.
- Enable the capture and use of methane which if vented to atmosphere is 21 times more greenhouse gas intensive than carbon dioxide.
- Capability for remote site generation; they are dependant only on the availability of biodegradable organic matter.
- Lower operating costs.
- Increased building value.
- REFIT tariff available.
- Operate extremely quietly.

#### Cons
- High capex cost.
- Combustion efficiency of biogas is low; approximately 60%.
- Additional maintenance and associated costs.
- Require commissioning.
3.1.9 Photovoltaic (PV) Systems

**Capex costs**
R65 000 – R120 000 per kW capacity.

**Savings**
Although PV systems exploit a free energy source, due to their high capex cost they currently have a lengthy payback period when compared solely to the cost of grid electricity. However, payback periods can be significantly reduced when additional value is created through supplementary revenue streams associated with the carbon market, energy security and advertising. In addition, the capex cost of BIPV systems should be offset against the cost of the alternative building material resulting in shorter payback periods.

**Description**
Photovoltaic (PV) modules convert solar energy into electricity; efficiencies currently vary from 8-20%.

Building Integrated Photovoltaics (BIPV) is the term used to describe the application of PV modules as an integrated component of the building façade; typically as part of the roof structure, building cladding or as a solar awning.

Currently in South Africa, the typical primary benefit of using PV systems is their ability to supply electrical power in non-grid electrified remote locations. Only systems generating in excess of 1MW can currently qualify for the REFIT enabling them to connect to the grid, negating the requirement for energy storage. In the eThekwini Municipal Area, smaller systems currently require stand alone energy storage devices such as electrochemical batteries.

**Applications**
Sunny locations where the national electricity grid is too far away for an economically feasible connection and/or high value is placed on a reliable, pollution and vibration free power supply.

### Pros
- Renewable energy.
- Remote site generation capability; dependant only on the availability of solar energy.
- Lack of moving parts means that modules rarely experience sudden failure and are considered reliable.
- Low maintenance.
- Long lifespan; typically, manufacturers guarantee modules to generate 80% of their rated capacity for 20-25 years.
- Can serve a secondary function as a component of the building façade.
- Lower operating costs.
- Zero GHG emissions produced during operation.
- Increased building value.
- REFIT tariff available.
- Operate extremely quietly.

### Cons
- Dependant on site specific availability of solar energy.
- High capex cost.
- Requires periodical inspection, maintenance and associated costs.
- Require commissioning.
3.1.10 Wind Turbine Systems

Capex costs
R4 000 – R70 000 per kW capacity.

Savings
Although wind energy systems exploit a free energy source, due to their high capex cost they currently have a fairly lengthy payback period when compared solely to the cost of grid electricity. However, payback periods can be significantly reduced when additional value is created through supplementary revenue streams associated with the carbon market, energy security and advertising.

Description
Wind turbines harvest the energy of wind, converting it into electricity. Horizontal Axis Wind Turbines (HAWTs) appear similar to the traditional windmill and are used extensively in developed countries for commercial energy generation. Vertical Axis Wind Turbines (VAWT), such as the one in the picture on the left, are rapidly becoming the wind turbine of choice in urban areas where gusty and turbulent winds prevail. Currently in South Africa, the typical primary benefit of using wind turbine systems is their ability to supply electrical power in non-grid electrified remote locations. Only systems generating in excess of one MW can currently qualify for the REFIT enabling them to connect to the grid, negating the requirement for energy storage. In the eThekwini Municipal Area, smaller systems currently require stand alone energy storage devices such as electrochemical batteries.

Applications
Windy locations where the national electricity grid is too far away for an economically feasible connection and/or where high value is placed on installing a pollution free power supply.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Renewable energy.</td>
<td>• Level of vibration must be considered when attaching to a building or house; dampening can be an extra expense.</td>
</tr>
<tr>
<td>• Relatively inexpensive renewable energy technology.</td>
<td>• Level of noise pollution must be considered when in an urban environment.</td>
</tr>
<tr>
<td>• Remote generation capability; dependant only on the availability of wind.</td>
<td>• Dependant on site specific availability of wind energy.</td>
</tr>
<tr>
<td>• Zero GHG emissions produced during operation.</td>
<td>• Relatively high capex cost.</td>
</tr>
<tr>
<td>• Lower operating costs.</td>
<td>• Requires periodical inspection, maintenance and associated costs.</td>
</tr>
<tr>
<td>• Increased building value.</td>
<td>• Require commissioning.</td>
</tr>
<tr>
<td>• REFIT tariff available.</td>
<td></td>
</tr>
</tbody>
</table>
3.2 Heating, Ventilation and Air-Conditioning (HVAC)

Capex costs
10-100% over and above the cost of standard units.

Savings
Often the additional cost of energy efficient units is indicative of their potential for energy savings i.e. expensive, yet highly efficient, units can operate at as much twice the efficiency of inefficient systems resulting in rapid payback periods.

Description
The majority of air-conditioning systems found in South Africa are of the electromechanical compression type.
When evaluating systems in terms of energy efficiency, the Coefficient of Performance (COP) is typically compared, the higher the COP the more efficient the system. The COP of a unit is the ratio of warmth/coolth generated, to the amount of electricity consumed. Currently, efficient units have COPs approaching 4 whilst inefficient units are closer to 2.
Importantly, the ability of a system to supply variable rates of air-conditioned air is critical to achieving optimum energy efficiency. The use of mechanical damping systems to control flowrate is inefficient. A more efficient alternative is the use of units fitted with variable speed drives (VSD) or variable air volume (VAV) systems. These systems are able to efficiently control the speed of the motors involved, thus producing the required air condition efficiently. Combining this type of control with individual climate control enables users to optimise their energy consumption by selecting the applicable power levels needed according to differing day-to-day conditions.

Applications
- Climate control in active or mixed mode ventilated buildings

#### Table 8: Summary of sectoral applicability for given ‘HVAC’ options

<table>
<thead>
<tr>
<th>Application</th>
<th>Home</th>
<th>Hotel</th>
<th>Restaurant</th>
<th>Office</th>
<th>Retail</th>
<th>School</th>
<th>Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.E. mechanical compression A.C</td>
<td>★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>Absorption chillers</td>
<td>★★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td>Heat &amp; Enthalpy Wheels</td>
<td>★★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td>Underfloor Air Distribution</td>
<td>★★</td>
<td>★★★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td>E.E. ducting</td>
<td>★★</td>
<td>★★★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★★</td>
</tr>
</tbody>
</table>

Key:
- Unlikely to be applicable
- Possibly applicable
- Likely to be applicable
- Highly applicable

3.2.1 Energy Efficient Electromechanical Air-conditioning

- Climate control in active or mixed mode ventilated buildings
### 3.2.2 Absorption Chillers

**Capex cost**
R4 000- R5 000 per kW capacity.

**Savings**
Currently, the realisation of savings is dependent on the use of low cost/zero cost heat as input fuel for an absorption chiller. In this event, monetary savings are typically 25-50% of the value of the cooling/heating provided in kWh.

### Description
Absorption units are able to generate heating or cooling in a similar manner to conventional electromechanical compression air-conditioning units. However, instead of using an electrical compressor to provide energy, absorption chillers utilise heat. Absorption chillers typically utilise a low cost source of heat, such as waste steam or hot water, to generate cooling or heating with typical COP values of 1 for cooling and between 1.2 -1.4 for heating. Currently in South Africa, the typical primary benefit of using these units is their ability to supply required cooling using waste heat.

### Typical applications
Locations where, relative to other fuels, the cost of electricity is high and there is a large supply of waste/free heat e.g. waste steam and solar energy. They are often added to combined heat and power plants to create tri-generation plants; electricity, heat and cooling.

### Pros
- Lower operating costs when utilising waste/free heat.
- Can utilise cleaner energy sources such as natural gas.
- Reduce size of conventional air-conditioning system required.
- Improved energy efficiency.
- Increased building value.
- Long lifespan.
- Reduced GHG emissions associated with fossil fuel energy consumption.

### Cons
- Additional capex cost.
- Additional maintenance and associated costs.
- Require commissioning.
### Capex cost
R60 000 – R70 000 per kW capacity.

### Savings
3-4% of the energy required by a standalone HVAC system.

### Description
Heat and Enthalpy wheels are rotary air-to-air heat exchangers that are able to extract heat/coolth from one airstream and transfer it to another. Adjacent supply and exhaust air counterflow streams each flow through half of the wheel. Heat wheels have a fill that transfers only sensible heat while an enthalpy wheel’s fill transfers total heat. Currently in South Africa, the typical primary benefits of using these units are their ability to reduce the size and operating cost of the HVAC system required.

### Typical applications
Projects that require a large percentage of outdoor air and have the exhaust air duct in close proximity to the intake.
Existing buildings with “sick building” syndrome and the amount of outdoor air intake must be increased.
New buildings where the required amount of ventilation air causes excess loads or where the desired equipment does not have sufficient latent capacity.

### Pros
- Compact and effective heat/coolth transfer systems.
- HVAC system size can be reduced.
- Improved energy efficiency.
- Lower operating costs.
- Reduced GHG emissions associated with fossil fuel energy consumption.
- Relatively low air pressure drop.
- Freeze protection is not an issue.
- Operate extremely quietly.

### Cons
- Requires that the two air streams be adjacent to each other.
- Air streams must be relatively clean and may require filtration.
- Requires periodical inspection and maintenance.
- Additional capex cost; adds to the initial HVAC cost.
- Additional maintenance and associated costs.
- Require commissioning.
3.2.4 Underfloor Air Distribution (UFAD)

Capex cost
Competitive with overhead air distribution systems.

Savings
- Energy: 18% of HVAC
- Cabling: ~ R20/m²
- Construction (floor-to-floor height): 200mm per floor
- Construction (sound insulation): ~ R19/m²
- Construction (slab levelling): ~ R15/m²

Description
Underfloor Air Distribution (UFAD) is a system using the underfloor plenum (open space between the structural concrete slab and the underside of a raised floor system) to deliver conditioned air directly into the occupied zone of the building. Air is delivered through supply outlets typically located at floor level or integrated as part of the office furniture and partitions. Return grilles are located above the occupied zone. This upward convection of warm air is used to efficiently remove heat loads and contaminants from the space. Currently in South Africa, the typical primary benefit of using these systems is the improved flexibility of ventilation supply.

Typical applications
UFAD can be effectively utilised for a wide range of building designs, however, in the past, the system has typically been utilised for general office space and data centres.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Improved flexibility for building services.</td>
<td>- Higher maintenance costs associated with build-up of dirt in plenum.</td>
</tr>
<tr>
<td>- Improved individual control; fewer hot/cold complaints.</td>
<td>- Air must be appropriately dehumidified before entering the underfloor plenum; otherwise condensation will occur on cool structural slab surfaces.</td>
</tr>
<tr>
<td>- Improved thermal comfort, productivity and health.</td>
<td></td>
</tr>
<tr>
<td>- Reduced life-cycle building costs.</td>
<td></td>
</tr>
<tr>
<td>- Reduced floor-to-floor height in new construction.</td>
<td></td>
</tr>
<tr>
<td>- Improved energy efficiency.</td>
<td></td>
</tr>
<tr>
<td>- Lower operating costs.</td>
<td></td>
</tr>
<tr>
<td>- Increased building value.</td>
<td></td>
</tr>
<tr>
<td>- Reduced GHG emissions associated with fossil fuel energy consumption.</td>
<td></td>
</tr>
</tbody>
</table>
3.2.5 Energy Efficient Ducting

**Capex cost**
Approximately R250-R350/m²; competitive with conventional steel ducting.

**Savings**
- Energy: 20% of HVAC
- Construction (floor-to-floor height): 200mm per floor

**Description**
Energy efficient ducting will soon be available as an alternative to conventional sheet metal ductwork in South Africa. Typically, the ducting has a core of insulative foam with aluminium laminated on both sides. The air-tightness of the technology together with the high insulative properties results in significant improvements in energy efficiency and reduced operating costs. The material is typically transported in sheets and assembled on site without the need for heavy machinery.

**Pros**
- Improved energy efficiency.
- Lower operating costs.
- Can be manufactured on site.
- Savings in transport costs.
- Reduced floor-to-floor height in new construction.
- Long lifespan due to anti-corrosive properties.
- Competitively priced.
- Reduced GHG emissions associated with fossil fuel energy consumption.

**Cons**
- Relatively fragile and care needs to be taken during handling, however it is easy to fix on site should there be any damage.
- The use of polyisocyanurate foam may result in certain restrictions in multi-storey buildings due to its fire rating. However, phenolic foam can be used as a replacement with no fire restrictions.

**Typical applications**
Can be effectively utilised for almost all air-conditioning applications where ducting is required.
3.3. Lighting Systems

When specifying lighting systems it is critical to understand the four key issues with respect to lighting systems, they are:

1. Lumens per Watt
2. Colour Temperature
3. Colour Rendering Index (CRI)
4. Lifespan

### Lumens per Watt

The lumen (lm) is the unit used to quantify the perceived power of light, luminous flux. Lumens per watt is a simple measurement of an electrical devices ability to produce visible light. Lux (lx) is the unit for illuminance or the amount of lumens per square metre.

For example: A flux of 1 000 lumens, concentrated into an area of 1 square metre, lights up the area with an illuminance of 1000 lux, whereas, the same 1 000 lumens dispersed over 2 square metres, produces a dimmer illuminance of only 50 lux.

### Colour Temperature

The colour temperature of a light source is the colour it appears to be, in relation to the colours of the visible spectrum and is measured in degrees Kelvin (K).

For example, a ‘white’ coloured lamp will appear to be ‘warm’ if it displays tones of red/yellow (~3 250K) and ‘cool’ if it displays tones of blue/green (~6 000K).

#### Table 10: Colour temperature of light and the typical applications of each

<table>
<thead>
<tr>
<th>Colour name</th>
<th>Warm tones</th>
<th>Neutral tones</th>
<th>Cool tones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural light condition</td>
<td>Sunrise/Sunset</td>
<td>Early morning</td>
<td>Midday</td>
</tr>
<tr>
<td>Typical Colour Temperature (K)</td>
<td>1 500K - 5 000K</td>
<td>5 000K - 8 000K</td>
<td>8 000K - 12 000K</td>
</tr>
<tr>
<td>Typical Application</td>
<td>Home</td>
<td>Home</td>
<td>Office</td>
</tr>
<tr>
<td></td>
<td>Retail</td>
<td>Retail</td>
<td>Industry</td>
</tr>
</tbody>
</table>
**Colour Rendering Index (CRI)**

Simply put, the colour rendering index (CRI) is a quantitative measure of the ability of a light source to reproduce the colours of various objects faithfully in comparison with an ideal or natural light source.

You will need to specify lighting with a high CRI value wherever it is necessary for people to observe the true colours of objects i.e. homes, offices, studios and retail stores.

Conversely, lighting with a low CRI value can be used wherever it is unnecessary for people to observe the true colours of objects i.e. storage areas, streets and other similar outdoor areas.

**Lifespan**

Lamps are often supplied with an expected lifespan printed on the packaging. However, the lifespan of an electrical light source is dependent on various factors including:

- Voltage
- Current spikes
- Frequency of switching on/off
- Local climatic conditions

Whenever any of the above vary from the specified operating conditions it is likely that the lifespan of the lamp will be shortened. In conclusion, use the expected lifespan as a guide and ensure that your buildings electrical circuits do not experience significant variances from specified operating conditions.

### 3.3.2 Incandescent Lighting

**Capex cost**

<table>
<thead>
<tr>
<th>Type of lamp</th>
<th>Lumens per Watt</th>
<th>Colour temperature (K)</th>
<th>Colour Rendering Index</th>
<th>Lifespan* (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household tungsten</td>
<td>~ 15</td>
<td>2700-3300</td>
<td>100</td>
<td>1 000-5 000</td>
</tr>
<tr>
<td>Glass halogen</td>
<td>~ 16</td>
<td>2900-3600</td>
<td>100</td>
<td>2 000-5 000</td>
</tr>
<tr>
<td>Quartz halogen</td>
<td>~ 24</td>
<td>2900-3600</td>
<td>100</td>
<td>2 000-5 000</td>
</tr>
</tbody>
</table>

*Savings can be achieved by either switching to other forms of lighting or reducing lamp wattage and combining with other more efficient forms of lighting to produce the desired lighting effect more efficiently.

**Description**

Incandescent lighting is an extremely inefficient form of lighting that is produced when an electric current passes through a thin metal filament, heating it until it produces light.

For a given quantity of light, an incandescent lamp consumes more power and produces more heat than fluorescent, LED and gas discharge lamps.

In addition to their poor luminous efficacy, the heat they produce also increases the work required by building cooling systems.

**Typical applications**

Due to the ‘warm’ tones and high colour rendering index produced by incandescent lamps they are typically used for general, display and ambient lighting.
### Capex cost
- Metal halide: R3.50 - R12.00 per Watt*
- LP sodium: R3.00 – R4.50 per Watt*
- HP sodium: R3.00 – R4.50 per Watt*

### Savings
Excluding mercury vapour lamps and based on the lumen output per Watt, savings of 66-93% can be achieved when compared to incandescent lighting alone.

### Description
Mercury vapour, metal halide, low pressure and high pressure sodium lamps are all gas discharge lamps that produce light when an electric current passes through an ionised gas, or plasma. Although their ability to produce visible light varies from relatively efficient to extremely efficient, they lose their peak performance relatively quickly whilst continuing to draw the same amount of power.

Of the gas discharge lamps discussed, mercury vapour lamps are the least efficient and should be replaced with more efficient lighting ensuring that they are disposed of correctly. The typical primary benefit of using these lamps is their ability to efficiently produce required high lux levels.

### Typical applications
Depending on the lamps characteristics but are typically used for warehouse, retail, outside and ambient lighting.

### Table 12: Incandescent lighting and their respective efficiencies

<table>
<thead>
<tr>
<th>Type of lamp</th>
<th>Lumens per Watt</th>
<th>Colour temperature (K)</th>
<th>Colour Rendering Index</th>
<th>Lifespan* (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury vapour</td>
<td>~44</td>
<td>5 000-6 000</td>
<td>35-55</td>
<td>20 000</td>
</tr>
<tr>
<td>Metal halide</td>
<td>~100</td>
<td>5 500-6 500</td>
<td>70-90</td>
<td>20 000</td>
</tr>
<tr>
<td>Low pressure sodium</td>
<td>~200</td>
<td>1 500-4 000</td>
<td>5-25</td>
<td>15 000</td>
</tr>
<tr>
<td>High pressure sodium</td>
<td>~100</td>
<td>2 000-3 000</td>
<td>20-40</td>
<td>20 000</td>
</tr>
</tbody>
</table>

*The lifespan is subject to the specific operating conditions

### Pros
- Relatively inexpensive.
- Produce ‘warm’ tones, similar to that of candlelight.
- Dimmable.
- Less toxic than many other types of lights.

### Cons
- Inefficient; generate a significant amount of heat thereby increasing the size of the HVAC system required.
- Short lifespan.
- Additional maintenance and associated costs.

*Price includes ballast; see section ‘electronic ballasts’
3.3.4 Fluorescent Lighting

Capex cost
- Tubes: R4-R7 per Watt*
- CFLs: R4-R7 per Watt
- Downlighters: R4-R7 per Watt

Savings
Based on the lumen output per Watt, savings of 50-85% can be achieved when compared to incandescent lighting alone.

Description
Fluorescent lighting is an efficient form of gas discharge lighting which utilises electricity in conjunction with a vapour and a phosphor to produce visible light. The typical primary benefit of using these lamps is their ability to efficiently produce required lux levels.

Typical applications
Fluorescent lamps are extremely versatile and come in many sizes, types, shapes, colours and light intensities.

### Table 13: Fluorescent lighting and their respective efficiencies

<table>
<thead>
<tr>
<th>Type of lamp</th>
<th>Lumens per Watt</th>
<th>Colour temperature (K)</th>
<th>Colour Rendering Index</th>
<th>Lifespan* (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T12 (old technology)</td>
<td>~ 75</td>
<td>~ 4 000</td>
<td>~ 65</td>
<td>5 000</td>
</tr>
<tr>
<td>T8 (warm white)</td>
<td>~ 88</td>
<td>~ 3 000</td>
<td>~ 50</td>
<td>20 000</td>
</tr>
<tr>
<td>T8 (cool white)</td>
<td>~ 94</td>
<td>~ 4 000</td>
<td>~ 65</td>
<td>20 000</td>
</tr>
<tr>
<td>T8 (daylight)</td>
<td>~ 78</td>
<td>~ 6 000</td>
<td>~ 75</td>
<td>20 000</td>
</tr>
<tr>
<td>T5 (warm white)</td>
<td>~ 96</td>
<td>~ 3 000</td>
<td>~ 50</td>
<td>20 000</td>
</tr>
<tr>
<td>T5 (cool white)</td>
<td>~ 105</td>
<td>~ 4 000</td>
<td>~ 65</td>
<td>20 000</td>
</tr>
<tr>
<td>T5 (daylight)</td>
<td>~ 80</td>
<td>~ 6 000</td>
<td>~ 75</td>
<td>20 000</td>
</tr>
<tr>
<td>CFL (warm white)</td>
<td>~ 72</td>
<td>~ 3 000</td>
<td>~ 50</td>
<td>15 000</td>
</tr>
<tr>
<td>CFL (cool white)</td>
<td>~ 75</td>
<td>~ 4 000</td>
<td>~ 65</td>
<td>15 000</td>
</tr>
<tr>
<td>CFL (daylight)</td>
<td>~ 60</td>
<td>~ 6 000</td>
<td>~ 75</td>
<td>15 000</td>
</tr>
</tbody>
</table>

*The lifespan is subject to the specific operating conditions and is a ROUGH guide only.

Pros
- Metal halide and low/high pressure sodium lamps are efficient.
- Low/high pressure sodium lamps produce ‘warm’ light.
- Metal halide lamps have a high CRI value.

Cons
- Mercury vapour lamps are inefficient.
- Generate a significant amount of heat thereby increasing the size of the HVAC system required.
- Relatively short lifespan.
- Additional maintenance and associated costs.

*Price includes electronic ballast
### Capex cost
R6 - R50 per Watt*

### Savings
LED's have a lumen output of 50-100 lumens per Watt. Based on the lumen output per Watt, savings of 52-87% can be achieved when compared to incandescent lighting alone.

### Description
LED lighting is an extremely efficient form of lighting produced when electricity flows through a phosphor coated semi-conductor diode. Commercial ‘white’ LEDs can produce up to 100 lumens per Watt; household incandescent lamps produce approximately 15 lumens per Watt and standard fluorescent lamps approximately 80 lumens per Watt.

It should be noted that LEDs are directional light sources and the efficiency in the direction of illumination is substantially greater than gas discharge and fluorescent lighting. Their potential for extremely long lifespan should be a key consideration when specifying LED lighting; approximately 50 000 hours whilst maintaining 50-70% of original intensity.

However, the overall performance of LEDs is directly proportional to the quality of the LED, the efficiency and reliability of the electrical drive circuitry as well as the thermal, optical and mechanical performance of the luminaire. These factors all need to be well integrated into a product to ensure that the maximum life span is achieved.

### Typical applications
LED lighting is extremely versatile with the list of suitable applications growing daily. Currently, the list includes tubelights#, downlights, uplights, strip-lights and floodlights, architectural lighting, under counter lighting, fridge and freezer lighting, signage and emergency lighting.

---

#### Pros
- Improved energy efficiency.
- Lower operating costs.
- Relatively high CRI value.
- Longer life than many other lamp types.
- Reduced GHG emissions associated with fossil fuel energy consumption.

#### Cons
- Higher capex cost than incandescent lamps.
- Contain hazardous elements that if not disposed of carefully will pollute the environment including precious water resources.

---

*Price is often indicative of quality; beware of poor quality lamps.

#Currently, there are problems with this technology as a replacement for fluorescent tubes.
3.3.6 Fibre Optic Lighting

Capex cost
R100 000 – R150 000 per installation.

Savings
Project specific.

Description
The two basic components of a fibre optic lighting system are a source of light and a bundle of optical fibres. In addition a decorative of diffusing fixture can be attached to the end of a bundle of optical fibres.

Optical fibres are hollow glass or plastic fibres that enable light to travel along a non-linear path through the process of reflection.

By arranging a bundle of optic fibres in the direct path of a source of light, the light can be ‘ducted’ to wherever it is required. The typical primary benefit of using fibre optic lighting is the ability to ‘duct’ light from one location to another.

Typical applications
Within the building industry optical fibre is used to transfer light for a wide range of applications ranging from general room lighting to decorative chandeliers. From an energy efficiency viewpoint, optical fibre can be used to ‘duct’ light from a free energy source such as the sun or from a central yet extremely efficient artificial, or active, light source.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely energy efficient.</td>
<td>High capex cost.</td>
</tr>
<tr>
<td>Lower operating costs.</td>
<td>Depending on quality, they can be sensitive to fluctuations in power supply.</td>
</tr>
<tr>
<td>Long lifespan.</td>
<td>Depending on quality, they can have a poor CRI value.</td>
</tr>
<tr>
<td>They are solid state devices and are thus more resistant to shock.</td>
<td></td>
</tr>
<tr>
<td>They emit very little heat.</td>
<td></td>
</tr>
<tr>
<td>Reduced GHG emissions associated with fossil fuel energy consumption.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved energy efficiency; they allow the ‘ducting’ of free or efficiently produced light.</td>
<td>Capex cost; currently they have a high capex cost.</td>
</tr>
<tr>
<td>Lower operating costs.</td>
<td></td>
</tr>
<tr>
<td>Long lifespan; fibre optic cables have a long life, estimates range from 15-40 years.</td>
<td></td>
</tr>
<tr>
<td>No electrical current required at the final point of use.</td>
<td></td>
</tr>
<tr>
<td>Increased building value.</td>
<td></td>
</tr>
<tr>
<td>Low maintenance.</td>
<td></td>
</tr>
</tbody>
</table>
Capex cost
Fluorescent: R1.50 - R3.00 per Watt
HID: R2.50 - R6.00 per Watt

Savings
5-15% of energy required by systems with magnetic ballasts.

Description
Ballasts are used to regulate the current for many lighting types. Electronic ballasts enable lamps to operate at higher efficacies and are able to reduce the flicker effect associated with fluorescent lighting by substantially increasing the frequency of power supply to the lamp. In addition, a higher operating frequency allows capacitance, as opposed to inductance, to be utilised to regulate the current to lamps which in turn enables fittings to more closely approach an “ideal reactance”.

The typical primary benefit of using electronic ballasts is their improved electrical efficiency over magnetic ballasts.

Pros
- Improved energy efficiency; more efficient than magnetic ballasts.
- Emit less heat than magnetic ballasts.
- Long lifespan; longer lifespan than magnetic ballasts.
- Lower operating costs.
- Low maintenance.
- Reduced GHG emissions associated with fossil fuel energy consumption.

Cons
- High capex cost if retrofitting lighting systems.

Typical applications
In the past magnetic ballasts were the norm, however modern electronic ballasts are more efficient and should be used for all new gas discharge and LED lighting installations. In addition, existing lighting circuits with magnetic ballasts should consider retrofitting with electronic ballasts.
### 3.3.9 Lighting Control

**Capex cost**
R50-R120 per m²

**Savings**
Wide-ranging.

**Description**
The large majority of automatic lighting control equipment available lowers energy consumption by reducing the amount of time lighting is switched on and/or by reducing the power required by the light fitting.
The manner in which the above is achieved varies from application to application but is usually primarily due to the use of the following devices:

- Motion sensor; lights are turned on for a set period of time whenever motion is detected.
- Timer; lights are turned on/off at certain periods of time.
- Relay; lights are turned on/off due to another event.
- Some combination of the above

**Applications**
Automatic lighting control systems should be used wherever there is a likelihood that occupants will leave lighting on when not required. However, particular care needs to be taken in areas where appropriate lighting is critical for health, in these areas automatic lighting control systems must not be able to pose any threat to human safety in the event of control failure.

**Pros**
- Low-to-moderate capital cost.
- Improved energy efficiency.
- Lower operating costs.
- Increased building value.
- Low maintenance.
- Long lifespan.
- Reduced GHG emissions associated with fossil fuel energy consumption.

**Cons**
- Additional capex cost.
- Additional maintenance and associated costs.
- Require commissioning.
3.4. Water Heating

Table 14: Summary of sectoral applicability for given ‘Water heating’ options

<table>
<thead>
<tr>
<th>Application</th>
<th>Home</th>
<th>Hotel</th>
<th>Restaurant</th>
<th>Office</th>
<th>Retail</th>
<th>School</th>
<th>Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar water heaters</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>Heat pumps</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
<tr>
<td>Waste heat recovery</td>
<td>★★★</td>
<td>★★</td>
<td>★★</td>
<td>★★</td>
<td>★★</td>
<td>★★★</td>
<td>★★★</td>
</tr>
</tbody>
</table>

Key:
- ★ Unlikely to be applicable
- ★ Possibly applicable
- ★★★ Likely to be applicable
- ★★★★ Highly applicable

3.4.1 Solar Water Heaters

**Capex cost**
R7 500 – R15 000 per kW of capacity.

**Savings**
50-80% when compared to electrical resistance heating.

**Description**
Solar water heaters are devices that use the sun’s radiant energy to heat water either directly or via a heat transfer fluid such as glycol. The typical primary benefit of solar water heaters is their ability to produce hot water without consuming electricity, thus saving on electrical bills.

Please refer to the relevant South African National Standards (SANS) document listed at the end of this document when finalising building design details related to this technology.

### Pros
- Renewable energy.
- Relatively inexpensive renewable energy technology.
- Remote generation capability; they are dependant only on the availability of solar energy.
- Zero GHG emissions produced during operation.

### Cons
- Additional capex cost; their capex cost is higher than electrical resistance heating.
- Require a backup heat source or additional storage for periods of insufficient solar energy.
- Additional maintenance and associated costs.
- Require commissioning.

**Typical applications**
In the building industry solar water heaters are used to heat swimming pools, general hot water and heat transfer fluids used in spatial heating systems. Often, a backup heating system is used for occasions when there is insufficient solar energy to match demand.
Capex cost
R2 500 - R5 000 per kW capacity.

Savings
50-83% of the energy required by electrical resistance heating.

Description
A heat pump uses the vapour compression cycle to remove heat from a low-temperature source and concentrate it where required. When extracting energy from ambient air a unit basically operates like an air-conditioner in reverse, as a consequence the by product of generating heat is cold, dry air which can be utilised to supplement the air-conditioning load. The typical primary benefit of heat pumps is their ability to produce hot water at a higher electrical efficiency than resistance heating, thus saving on electrical bills.

Pros
- Improved energy efficiency; 2-5 times more efficient than electrical resistance heating.
- Can be placed out-of-sight of the general public inside a plant room.
- Freeze protection is not an issue.
- By product of air-to-water heating process is cool dry air which can be used to supplement AC system.
- Lower operating costs.
- Increased building value.
- Low maintenance.
- Long lifespan.

Cons
- Additional capex cost; their capex cost is higher than electrical resistance heating.
- Require a backup heat source or additional storage for periods of cold weather.
- Additional maintenance and associated costs.
- Require commissioning.
- Lifespan typically shorter than solar water heaters.

Typical applications
Wherever water temperatures up to 70°C are required i.e. homes, schools, hospitals, hotels, gyms and industry.
3.4.3 Waste Heat Recovery Systems

**Capex cost**
Wide ranging and dependant on the characteristics of available waste heat; difference in temperature, pressure and fluid properties.

**Savings**
Wide ranging and dependant on the characteristics of available waste heat; difference in temperature, pressure and fluid properties.

**Description**
A waste heat recovery system captures waste heat from one process which can then be used to provide heat to another. If the waste heat is at a lower temperature than that required, than the system can be used in conjunction with another technology such as a heat pump or solar water heating to provide the required temperature. The typical primary benefit of using waste heat recovery systems is their ability to produce hot water from waste heat, thus saving on electrical bills.

**Typical applications**
In the building sector heat recovery systems are often used to capture and transfer waste heat from large central air conditioning systems for spatial heating, heated swimming pools or potable hot water.

**Pros**
- Improved energy efficiency.
- Utilise waste heat usually at 70-90% efficiency.
- Lower operating costs.
- Long lifespan; average lifespan is approximately 15-20 years.
- Low maintenance; typically robust technology.
- Reduced GHG emissions associated with fossil fuel energy consumption.

**Cons**
- Additional capex cost.
- Additional maintenance and associated costs.
- Require commissioning.
3.5 Motors and Drives

Table 15: Summary of sectoral applicability for given ‘Motors & Drives’ options

<table>
<thead>
<tr>
<th>Application</th>
<th>Home</th>
<th>Hotel</th>
<th>Restaurant</th>
<th>Office</th>
<th>Retail</th>
<th>School</th>
<th>Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.E. motors</td>
<td>●</td>
<td>●●●</td>
<td>●●</td>
<td>●●●</td>
<td>●●●</td>
<td>●●●</td>
<td>●●●</td>
</tr>
<tr>
<td>Variable Speed Drives</td>
<td>●●●</td>
<td>●●</td>
<td>●</td>
<td>●</td>
<td>●●●</td>
<td>●●●</td>
<td>●●●</td>
</tr>
<tr>
<td>Soft starters</td>
<td>●●●</td>
<td>●●</td>
<td>●</td>
<td>●</td>
<td>●●●</td>
<td>●●●</td>
<td>●●●</td>
</tr>
</tbody>
</table>

Key:
- Unlikely to be applicable
- Possibly applicable
- Likely to be applicable
- Highly applicable

3.5.1 Energy Efficient Motors

Capex cost
R800 – R2500 per kW dependent on size, speed and specification.
Additional capex cost, over and above standard motors, 15-20%.

Savings
3-10% of that compared to standard motors.

Description
Although modern energy efficient motors are slightly more efficient than standard motors at full load, the real difference occurs at partial loads where the efficiency of standard motors can drop significantly relative to efficient motors.

Pros
- Improved energy efficiency.
- Lower operating costs.
- Long lifespan; less heat is emitted, prolonging the lifespan.
- Higher Service Factor allows intermittent operation higher voltage peaks.
- Recommended for voltage variation applications.
- Low maintenance.
- Typically longer warranty period
- Reduced GHG emissions associated with fossil fuel energy consumption.

Cons
- Additional capex cost.
### 3.5.2 Variable Speed Drives (VSDs)

**Capex cost**
R900 - R3 500 per kW

**Savings**
The level of savings is dependent on the type of motor load of which there are three main types:

1. Variable torque loads incl. pumps and centrifugal fans.
2. Constant torque incl. positive displacement compressors, conveyors and agitators
3. Constant power incl. motor driven tools

Generally, VSDs can realise 10-50% savings for the first two types but are not suited to the third type.

**Description**
A variable speed drive is able to control the rotational speed of an alternating current motor by controlling the frequency of the power supply to the motor. The variable frequency and subsequent variable voltage enables the efficient operation of induction motors at different speeds.

**Typical applications**
Motors that regularly operate at partial load should be fitted with variable speed drives. In the building industry typically, this would apply to pumps and centrifugal fans but could also apply to positive displacement compressors, conveyors and motor driven tools.

### Pros
- Improved energy efficiency.
- Lower operating costs.
- Low maintenance.
- Longer lifespan of motors; comprehensive electronic motor protection included.
- Better process control; speed variation and torque control.
- Increased production; speed variation and torque control.

### Cons
- Additional capex cost.
- Relatively sensitive to poor power quality problems such as voltage and current surges, over/under current and over/under voltage.
- Additional maintenance and associated costs.
3.5.3 Soft Starters

Capex cost
R400 – R1 100 per kW.

Savings
Although dependant on several factors, for loads that operate for less than 50% of the time energy savings of up to 18% can be achieved. Major factors influencing savings include:

- Amount of time the motor is operated per day.
- The percentage load when operated at part load.
- Motor size; the larger the motor the greater the savings.

Description
A soft starter is used to accelerate a motor from zero speed to rated speed over a user adjustable period of time. The process is achieved by controlling the voltage applied to the motor terminals during starting. The reduced voltage results in a reduced starting current and torque, resulting in less demand on the power distribution system and reduced strain on equipment.

Typical applications
Motorised applications that require intermittent starting and stopping.

Pros
- Improved energy efficiency.
- Lower operating costs.
- Less maintenance; reduce maintenance concerns related to the life of the contacts on electromechanical motor starters.
- Longer lifespan of motors; motors can be switched off without significant fear of degradation caused during start-up.
- Longer lifespan of equipment; extend the life of belts, chains, gearboxes, shafts, bearings and machine mountings.
- Pump “Water Hammer” reduction.
- Reduced GHG emissions associated with fossil fuel energy consumption.

Cons
- Start-up torque is reduced.
- Additional capex cost.
- Relatively sensitive to poor power quality problems such as voltage and current surges, over/under current and over/under voltage.
- Additional maintenance and associated costs.
3.6 Management

Table 16: Summary of sectoral applicability for given ‘Management’ options

<table>
<thead>
<tr>
<th>Application</th>
<th>Home</th>
<th>Hotel</th>
<th>Restaurant</th>
<th>Office</th>
<th>Retail</th>
<th>School</th>
<th>Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM Systems</td>
<td>♦</td>
<td>♦</td>
<td></td>
<td>♦</td>
<td>♦</td>
<td>♦</td>
<td>♦</td>
</tr>
<tr>
<td>Power factor correction</td>
<td>♦♦</td>
<td>♦♦</td>
<td></td>
<td>♦♦</td>
<td>♦♦</td>
<td>♦♦</td>
<td>♦♦</td>
</tr>
<tr>
<td>Commissioning</td>
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<td>♦♦</td>
<td></td>
<td>♦♦</td>
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<td>♦♦</td>
<td>♦♦</td>
</tr>
<tr>
<td>Retrocommissioning</td>
<td>♦♦</td>
<td>♦♦</td>
<td></td>
<td>♦♦</td>
<td>♦♦</td>
<td>♦♦</td>
<td>♦♦</td>
</tr>
<tr>
<td>Energy Auditing</td>
<td>♦♦♦</td>
<td>♦♦♦</td>
<td></td>
<td>♦♦♦</td>
<td>♦♦♦</td>
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<td>♦♦♦</td>
</tr>
<tr>
<td>Monitoring &amp; Verification</td>
<td>♦♦♦</td>
<td>♦♦♦</td>
<td></td>
<td>♦♦♦</td>
<td>♦♦♦</td>
<td>♦♦♦</td>
<td>♦♦♦</td>
</tr>
</tbody>
</table>

Key:
- Unlikely to be applicable
- Possibly applicable
- Likely to be applicable
- Highly applicable

3.6.1 Building Management Systems

Capex cost
R120 –R180 per square metre of building.

Savings
20% of overall building energy consumption.

Description
Modern buildings rely upon a variety of energy dependant systems to provide services such as air-conditioning, ventilation, lighting, entertainment and security.

Building management systems (BMSs) are a form of centralized control that can be programmed to control these systems electronically, optimising their use to meet the needs of building occupants with minimum energy consumption whilst removing the likelihood of human inefficiency.

In addition, BMSs can assist with building operation and maintenance strategies by logging equipment specific energy consumption data such as operational periods and energy draw. When they are programmed correctly and properly commissioned they are generally effective at reducing energy consumption. However, when damaged, incorrectly programmed or poorly commissioned the results can be poor indoor environment quality, loss of productivity and higher utility bills.

Typical applications
Buildings with a high percentage of energy dependant systems with electronic control capability.
3.6.2 Power Factor Correction

Capex cost
R200-R300 per kVAr

Savings
R40-R80 per kVA per month.

Description
Power factor is the ratio of power consumed in kW to the power required in kVA. Since many tariffs include a maximum demand charge (kVA) it is important to ensure that a building's power factor is as close to unity as possible.

Typically, power factor is corrected by the addition of capacitance to the circuit.

Modern digital power factor correction systems, although more expensive than mechanical systems, are able to respond to changes in power factor faster and have a longer expected lifespan.

Typical applications
Buildings with large HVAC systems and large amounts of computers and gas discharge lighting systems, including fluorescent lighting.

Pros

- Improved energy efficiency; improve a building's overall power efficiency in terms of consumption and demand.
- Lower operating costs.
- Long lifespan; average lifespan is 10-20 years.

Cons

- Additional capex cost.
- Additional maintenance and associated costs.
- Require commissioning.
3.6.3 Commissioning

**Capex cost**
R20-R30 per square metre of building.

**Savings**
10-50% of a comparable non-commissioned building.
80% of savings persist for at least three years after the commissioning process is complete.

**Description**
The realisation of a building’s long term performance requirements is dependent on the continuous successful operation of the building various systems. Therefore it is essential that the building’s system operators have a thorough understanding of the relevant aspects of the systems for which they are responsible and is achieved through a comprehensive commissioning process.

**Typical applications**
The process should be applied to all new buildings. The complexity of the process will vary according to the size, number and technology of the building systems involved i.e. a house typically requires only a basic commissioning process between the owner and individual system representatives, whereas a large commercial building typically requires a commissioning agent and a fair amount of time with section managers, various operators and maintenance staff. In addition to personnel training it is important to ensure that system monitoring is in place in order to verify building performance.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| ● Improved energy efficiency; educating operators to understand building system operation reduces the chances that they will inadvertently negatively modify or override system settings essential to maintaining performance.  
● Lower operating costs; reduced electricity bills due to optimisation of systems.  
● Shortened payback periods; the payback period on systems including will be shortened due to system optimisation.  
● Reduced GHG emissions associated with fossil fuel energy consumption. | ● Additional cost. |
### 3.6.4 Retrocommissioning

#### Capex cost
R20-R30 per square metre of building.

#### Savings
10-50% of a comparable non-commissioned building.
80% of savings persist for at least three years after the commissioning process is complete.

#### Description
Retrocommissioning is the optimisation of building systems and training of system operators in existing buildings. Building performance often declines 2-5 years after commissioning and the opportunity for energy savings through retrocommissioning is usually substantial.

#### Typical applications
All buildings that have either not been commissioned or have been inadequately managed since initial commissioning or where it has been longer than 3 years since last commissioning process.

<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved energy efficiency; educating operators to understand building system operation reduces the chances that they will inadvertently negatively modify or override system settings essential to maintaining performance.</td>
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<tr>
<td>Reduced GHG emissions associated with fossil fuel energy consumption.</td>
<td></td>
</tr>
<tr>
<td>Additional cost.</td>
<td></td>
</tr>
</tbody>
</table>
3.6.5 Energy Auditing

Cost
Energy audit fee structures vary from fixed fees through to performance-based and savings-based fees. Often, the level of detail required and previous energy management history will influence the type of fee structure utilised.

Savings
10-50% of a comparable non-audited or poorly operated building.

Description
Energy audits identify where and when energy is consumed within a building. In addition, they should identify where potential savings opportunities are and the ways in which to reduce energy consumption.

Once recommendations have been assessed and case studies compared, relevant personnel can start to build the business case for investment whether it be in behavioral change, efficient technology or modifications to daily operation.

The level of detail involved in an energy audit differs, from a simple walk through audit through to a detailed analysis of capital intensive interventions.

Typical phases of a detailed energy audit as part of an energy management program:

1. Inception meeting and gathering of available information.
2. Initial comparison to other buildings of similar size and function.
3. Establish when energy is used.
4. Establish where energy is used.
5. Eliminate waste.
7. Optimize energy supply.
8. Verify.
9. Compare again and continue to improve.

Typical applications
All buildings that have never had an energy audit or where it has been longer than 3 years since the last audit.

STEP-BY-STEP ENERGY AUDIT GUIDE

1) Health and Safety Check
   • Testing for Carbon Monoxide, Gas Leaks and Chimney Draft on all Combustion appliances in order to insure good indoor air quality.

2) Furnace/Boiler Monitoring
   • Measuring the efficiency and performance of heating / boiler system and domestic hot water by measuring flue gases.

3) Blower Door Testing
   • Testing the convective losses (leakiness) of the home by depressurising the home to 50 pascals using a Minneapolis Blower Door.

4) Infrared Camera inspection
   • Complete inspection of the entire thermal boundary with the use of infrared thermal imaging to assess insulation levels.

5) Electrical Load Quantification
   • Inventorying of electrical load and direct quantification of major appliances using Kill-a-Watt meter to determine average approximate yearly usage.

6) Utility Bill Analysis
   • Examination of past and present utility bills in order to determine usage patterns and to target most effective energy improvement measures.

7) Water efficiency Determination
   • Analysis of water use efficiency of faucets, sinks, and showers using water weir flow meter.

8) Computer Modeling Study
   • Based on the findings of the above studies, a holistic building model is built specifically for your home and then tests are run to determine the most cost-efficient means of reducing energy use.

9) Report Generation and ENERGY IQ Assignment
   • All of the above data is compiled into a single comprehensive report that outlines strategies to be taken, approximate costs, and payback periods for energy conservation and efficiency measures to be implemented.

10) Follow-Up Inspection
    • A follow-up inspection is made after energy conservation and efficiency projects are completed in order to insure that all works

Pros
- Improved energy efficiency.
- Lower operating costs.
- Reduced GHG emissions associated with fossil fuel consumption.

Cons
- Additional cost.
3.6.6 Monitoring and Verification (M&V)

Cost
Project specific.

Savings
Project specific.

Description
Measurement and verification, with respect to energy related projects, entails the recording and assessment of energy data to establish baseline energy characteristics and/or to verify actual energy savings.

Data logging equipment is often installed whether for ease of assessment, time-of-use assessment or to isolate savings on specific interventions. However, rudimentary M&V can be accomplished by analysing the effect of interventions on the sites overall utility bill.

M&V is particularly valuable when verifying performance-based contracts and installs confidence in project financiers that an energy project will realise the savings necessary to fulfil debt obligations.

Typical applications
Baseline energy characteristics and energy project verification.

Pros
- Valuable when establishing an energy baseline.
- Verifies predicted energy savings.
- Can reduce risk to building owner/financier.

Cons
- Additional cost
4 List of Relevant Standards

General standards

1. SANS 10400-A: The application of the National Building Regulations – Part A: General principles and requirements.

2. SANS 204-1: Energy efficiency in buildings – Part 1: General requirements

3. SANS 204-2: Energy efficiency in buildings – Part 2: The application of the general requirements in buildings with natural environmental control.

4. SANS 204-3: Energy efficiency in buildings – Part 3: The application of the general requirements in buildings with artificial, or active, environmental control.

5. SANS 10142-1: The wiring of premises – Part 1: Low-voltage installations

Standards specific to foundations


Standards specific to heating ventilation and air-conditioning (HVAC)

7. SANS 10400-O: The application of the National Building Regulations – Part O: Lighting and ventilation.

Standards specific to lighting


Standards specific to fire protection


Standards specific to water heating

11. SANS 151: Fixed electric storage water heaters.

12. SANS 10254: Installation, maintenance, replacement and repair of fixed electric storage water heating systems.

13. SANS 1307: Domestic solar water heaters

14. SANS 10106: Installation, maintenance, replacement and repair of domestic solar water heating systems.
5 List of local suppliers and service providers

5.1 Green Building

The following have been arranged in alphabetical order. Note that this is not a comprehensive listing:

**East Coast Architects**
East Coast Architects, established in 1996, is a network of forward thinking and award winning architects who have a shared positive vision for the eastern seaboard of Southern Africa. As a team of individuals they bring complimentary skills to the practice and recognise that each occupy individual areas of specialization including both Community/Social and Environmental/Sustainable architecture.
Email: eca@arqus.co.za
Tel: 031 205 8616 083 610 0545

**EcoBuild Technologies**
The company has been instrumental in developing the Ecobeam method of sandbag building in order to meet the need to develop an alternative affordable and eco-friendly building solution.
Website: www.ecobuildtech.co.za
Tel: 021 531 7043

**Eco Design Architects**
Eco Design is an architectural practice which specializes in ecological friendly Green building and consulting. Established in 1998 by Andy Horn, the practice has been at the forefront of the Green building movement in South Africa and has won a number of international awards in the field of sustainable design.
Website: www.ecodesignarchitects.co.za
Tel: 021 855 2963

**EnviroMinds**
EnviroMinds employs an integrated design approach whereby project participants work together from the onset of a project. The aim of their knowledgeable consultants and designers is to achieve high performance projects that reach beyond sustainable development into the realm of positive development.
Website: www.envirominds.org
Tel: 087 808 2262

**Greenbuild SA**
The company’s in-house architects have the capability to design quality SIP buildings suited to the use of their own SIP product.
Website: www.ecobuildtech.co.za
Tel: 021 531 7043

**Green by Design, powered by WSP**
The company offers expertise in energy and resource efficient building design and property development planning, specialising in consulting, project managing and designing Green initiatives for new and existing buildings.
Website: www.wspgroup.co.za
Tel: 031 240 8800
**Koop**
Koop’s design ethos is to produce buildings and products that are environmentally sensitive and energy efficient. A crossover between architectural and furniture design informs Koop’s work; the furniture is approached structurally and the architecture may be assembled like large pieces of furniture.
Website: www.koopdesign.co.za
Tel: 031 303 3922

**Malcolm Worby Designs**
Malcolm Worby Designs is an award-winning design consultation firm that specialises in the design of natural, sustainable, and environmentally friendly buildings.
Website: www.malcolmworby.com
Tel: 021 855 2963

**Pennington & Associates**
Pennington & Associates recognizes that a team is only as strong as its weakest link and has consequently built a service strategy over the years that takes cognizance of this. Teamwork, whether within the practice or in its relationships with clients and key consultants, remains the guiding principle.
Website: www.penningtonassociates.co.za
Tel: 031 261 2360

### 5.2 Energy Efficiency

The following have been arranged in alphabetical order. Note that this is not a comprehensive listing:

**Associated Energy Services (AES)**
AES is an energy company providing outsourced energy solutions via a Contract Energy Management (CEM) mechanism.
Website: www.aes-africa.com
Tel: 021 532 3381

**Enviroduct**
The company sells and installs energy efficient HVAC ducting.
Website: www.enviroduct.co.za
Tel: 031 700 1479

**Energywise**
The company offers a variety of energy efficient products and also consults with respect to energy efficiency.
Website: www.energywise.co.za
Tel: 031 764 2345

**EnviroMinds**
The experienced energy consultants of this small, yet highly dynamic, company have the expertise necessary to provide quality information to their clients enabling better energy management, improved energy efficiency and a practical path to the use of cleaner energy alternatives.
Website: www.envirominds.org
Tel: 087 808 2262

**Lightkinetics**
The company specialises in energy efficient lighting systems.
Website: www.lightkinetics.com
Tel: 011 728 1249
5.3 Renewable Energy Generation

The following have been arranged in alphabetical order. Note that this is not a comprehensive listing:

**Biotech**
The company specialises in the manufacture and distribution of biodiesel.
Website: www.biotechsa.net
Tel: 051 445 2173

**EnviroMinds**
The experienced energy consultants of this small, yet highly dynamic, company have the expertise necessary to provide quality information to their clients enabling better energy management, improved energy efficiency and a practical path to the use of cleaner energy alternatives. As an energy service company (ESCo), we are capable of supplying and installing the majority of the recommended technologies specified by our engineering staff.
Website: www.envirominds.org
Tel: 087 808 2262

**Fuel Cells Africa**
The company specialises in fuel cell sales and installation.
Website: www.fuelcellsafrica.com
Tel: 011 467 1929

**Vardhan Power 4U**
The company has been in operation for the past 6 years and specialises in solar energy and passive building solutions/products.
Website: www.vardhanpower4u.co.za
Cell: 071 6828278
The following have been arranged in alphabetical order:

**Agrement SA**
Agrément South Africa serves the national interest by being the internationally acknowledged, independent South African centre serving the building and engineering communities by providing assurance to specifiers and users via technical approvals for the fitness for purpose of non-standardised and/or unconventional products.
Website: www.agrement.co.za

**BioRegional**
BioRegional is an entrepreneurial charity, which initiates practical sustainability solutions, and then delivers them by setting up new enterprises and partnerships around the world. We assist and encourage others to achieve sustainability through consultancy, education and informing policy.
Website: www.bioregional.com

**City Architects (eThekwini Municipality Architectural Department)**
Website: www.durban.gov.za/durban/services/engineering/architecture

**Department of Minerals and Energy**
Website: www.dme.gov.za

**ecospecifier SA**
ecospecifier SA aim is to help building professionals including architects, designers, builders and specifiers, as well as keen homeowners, to shortcut the eco and healthy materials sourcing process.
Website: www.ecospecifier.co.za

**Energy Information Administration**
The Energy Information Administration is a United States’ government run organization specializing in energy statistics.
Website: www.eia.doe.gov

**Enviropaedia**
Enviropaedia is an online environmental encyclopaedia linked to a Green directory with a sustainable living guide and leading edge articles on sustainable development.
Website: www.enviropaedia.com

**Eskom**
Eskom is South Africa’s major electricity utility.
Website: www.eskomdsmp.co.za/

**eThekwini Municipality Electricity Department**
Website: www.durban.gov.za/durban/services/electricity

**eThekwini Municipality Environmental Management Department**
Website: www.durban.gov.za/durban/services/environment

**Green Building Council of South Africa**
The Green Building Council of South Africa (GBCSA) is an independent, non-profit organization spearheaded by leaders from all sectors of the commercial property industry. Launched in 2007, the Green Building Council aims to promote and facilitate Green building practices through market-based solutions.
Website: www.gbcsa.org.za
Imagine Durban
Imagine Durban is a council-led project on integrated, long-term planning. It is being implemented in conjunction with Sustainable Cities, an NGO from Canada, and the PLUS Network, a network of 35 cities sharing experiences in sustainability planning.
Website: www.imaginedurban.org

National Home Builder’s Registration Council (NHBRC)
The National Home Builders Registration Council was established in terms of the Housing Consumer Protection Measures Act, 1998 (Act No. 95 of 1998). The Council is mainly established to protect the interest of housing consumers, and to regulate the home building industry.
Website: www.nhbrc.org.za

One Planet Living
One Planet Living is a global initiative based on 10 principles of sustainability developed by BioRegional and the World Wildlife Fund (WWF.)
Website: www.oneplanetliving.org

Rocky Mountain Institute (RMI)
RMI is an American independent non-profit organization, whose mission is to drive the efficient and restorative use of resources. RMI’s style is nonadversarial and transideological, emphasizing integrative design, advanced technologies, and mindful markets. RMI works extensively with the private sector, as well as with civil society and government, to create abundance by design and to apply the framework of Natural Capitalism.
Website: www.rmi.org

South African Bureau of Standards (SABS)
SABS is a statutory body that was established in 1945 and continues to operate in as the national institution for the promotion and maintenance of standardization and quality in connection with commodities and the rendering of services.
Website: www.sabs.co.za

Sustainable Energy Society of Southern Africa (SESSA)
SESSA is a non profit organisation dedicated to the use of renewable energy and energy efficiency.
Website: www.sessa.org.za

Thermal Insulation Association of South Africa (TIASA)
TIASA promotes the benefits of insulation. Although providing a service to all industries, its initial focus is the development of its products & services for the building and construction industry with specific attention being paid to energy efficient affordable homes.
Website: www.tiasa.org.za

Urban Sprout
Urban sprout is an award winning blog-style online community, featuring daily Green blogs, events and a directory that focuses on organic and eco-friendly products.
In addition the site deals with issues such as organic food, climate change, ethical consumerism, sustainable lifestyles and environmental justice.
Website: www.urbansprout.co.za
The following have been arranged in alphabetical order:

**Alternative energy:** Energy from non-conventional fossil fuelled sources such as oil, coal and natural gas.

**Biodiversity:** The combination of all living animals, plants, fungi and micro-organisms in a region.

**Biomass:** Plant matter such as trees, grasses, agricultural crops or other biological material.

**Building envelope:** The exterior surface of a building’s construction including the walls, windows, roof and floor.

**Building Management System:** Software based system to automatically control building services.

**Cetane number:** Cetane number a measurement of the combustion quality of diesel fuel during compression ignition. It is a significant expression of diesel fuel quality among a number of other measurements that determine overall diesel fuel quality.

**Cogeneration:** The simultaneous production of electrical or mechanical power and useful thermal energy from the same fuel energy source.

**Commissioning:** The process of putting building services systems into active practise. This includes testing and adjusting HVAC, electrical, plumbing and other systems to assure proper functioning and adherence to design criteria, and instructing building representatives in their use.

**Climate change:** The climate phenomenon largely attributed to human activities in particular the use of greenhouse gas intensive fossil fuels.

**Cradle-to-cradle:** Design methodology that takes into account all stages of the life cycle of a product, service or building but does not seek to revive it after disposal.

**Daylight factor (DF):** The proportion of internal illuminance (light level) compared to the external illuminance, expressed as a percentage. Daylight factor represents the proportion of external light which illuminates a given external surface.

**Demand Charge:** Some electricity tariffs include a “demand charge” as an added cost over and above the charge for electricity consumed (kWh). The demand charge is based on the maximum amount of apparent power required by the site, measured in kVA.

**Displacement ventilation:** Supply air is introduced to the space at or near the floor level, at a low velocity, at a temperature only slightly below the desired room temperature. The cooler supply air ‘displaces’ the warmer room air, creating a zone of fresh cool air at the occupied level. Heat and contaminants produced by activities in the space rise to the ceiling level where they are exhausted from the space. This results in an efficient and low power ventilation system.

**Ecosystem:** An interconnected and symbiotic grouping of animals, plants, fungi and micro-organisms that sustain life through biological, geological and chemical activity.

**Greenfield site:** Land on which no development has previously taken place; usually understood to be on the periphery of an existing built up area.

**Greenhouse gases:** Trace gases such as carbon dioxide, water vapour, methane and CFCs that are relatively transparent to the higher-energy sunlight, but trap the lower-energy infrared radiation.

**Greenwash:** Disinformation disseminated by an organisation so as to present an environmentally responsible public image.
**Grid:** A term used to describe the network of wires and cables which transport electricity from a power plant.

**Habitat:** (1) The natural home of an animal or plant; (2) The sum of the environmental conditions that determine the existence of a community in a specific place.

**Holistic:** A wide reaching approach to a theory, a task, or a problem that encompasses all the elements of the system because of the interdependency of those elements.

**Kilowatt hours (kWh):** Electricity consumed is measured in kilowatt hours (kWh). A kWh is calculated by multiplying the number of watts (W) or kilowatts (kW) an appliance / machine requires by the number of hours used.

**Landfill:** An area where solid waste is deposited. In a sanitary facility, a hole in the ground is lined so that material will not escape, and it is covered with layers of dirt as it is progressively filled. When completely filled, it is capped and sealed with more dirt and topsoil.

**Natural environment:** The concept of the natural environment can be distinguished by the following components, and is in contrast to the built environment:

- Complete ecological units that function as natural systems without massive human intervention, including all vegetation, animals, microorganisms, soil, rocks, atmosphere and natural phenomena that occur within their boundaries.

- Universal natural resources and physical phenomena that lack clear-cut boundaries, such as air, water, and climate, as well as energy, radiation, electric charge, and magnetism, not originating from human activity.

**Psychrometric chart:** A chart showing the air’s dry and wet bulb temperatures, humidity, moisture content and enthalpy.

**Relative Humidity (RH):** Ratio of the amount of water vapour in air at a specific temperature to the maximum capacity of the air to hold moisture at that temperature.

**Renewable energy:** An energy source that, from an earth perspective, is continually replenished.

**Sustainable development:** An approach to progress that meets the needs of the present without compromising the ability of future generations to meet their needs.

**Thermal comfort:** A means of describing occupant comfort which takes into account air temperature, radiant temperature, humidity, draught, clothing value and activity rates.

**Triple bottom line:** The concept of triple bottom line accounting means expanding the traditional reporting framework to take into account ecological and social performance in addition to financial performance.

**VAV systems:** Variable Air Volume air conditioning systems.

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The following have been arranged in alphabetical order:

- **a:v ratio**  Area to Volume ratio
- **Ah**  Amp hours
- **BIPV**  Building Integrated Photovoltaic
- **BMS**  Building Management System
- **BPS**  Building Performance Simulation
- **Capex**  Capital expenditure
- **CBD**  Central Business District
- **CFL**  Compact Florescent Lamp
- **CHP**  Combined Heat and Power
- **CH4**  Methane
- **CO2**  Carbon Dioxide
- **COP**  Co-efficient Of Performance
- **CRI**  Colour Rendering Index
- **deg. C**  degrees Centigrade
- **EIA**  Environmental Impact Assessment
- **fc**  foot candle
- **GHG**  Green House Gas
- **GWh**  Gigawatt-hour
- **GWP**  Global Warming Potential
- **HAWT**  Horizontal Axis Wind Turbine
- **HID**  High Intensity Discharge
- **H.P.**  High Pressure
- **HVAC**  Heating, Ventilation, and Air conditioning
- **IPP**  Independent Power Producers
- **J**  Joule
- **kg**  kilogram
- **kgCO2eq/kg**  kilograms of Carbon Dioxide equivalent per kilogram
- **kg/m³**  kilograms per meter cubed
- **kJ**  kilojoules
- **kVA**  kilovolt amperes
- **kW**  kilowatt
- **kWh**  kilowatt-hour
- **kWh/kg**  kilowatt hours per kilogram
- **kWh.m⁻².day⁻¹**  kilowatt hours per meter squared per day
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
</tr>
<tr>
<td>L.P.</td>
<td>Low Pressure</td>
</tr>
<tr>
<td>LPG</td>
<td>Liquid Petroleum Gas</td>
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<tr>
<td>lx</td>
<td>lux</td>
</tr>
<tr>
<td>m/s</td>
<td>meters per second</td>
</tr>
<tr>
<td>mm</td>
<td>millimeters</td>
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<tr>
<td>M&amp;V</td>
<td>Monitoring and Verification</td>
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<tr>
<td>MW</td>
<td>Megawatt</td>
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<tr>
<td>NBR</td>
<td>National Building Regulations</td>
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<tr>
<td>NERSA</td>
<td>National Energy Regulator of South Africa</td>
</tr>
<tr>
<td>NO₂</td>
<td>Nitrous Oxide</td>
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<tr>
<td>Opex</td>
<td>Operational expenditure</td>
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<tr>
<td>PCP</td>
<td>Power Conservation Program</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
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<tr>
<td>PV</td>
<td>Photovoltaic</td>
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<tr>
<td>R/kWh</td>
<td>Rands per kilowatt-hour</td>
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<tr>
<td>R-value</td>
<td>Resistance to heat transfer value</td>
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<tr>
<td>REFIT</td>
<td>Renewable Energy Feed In Tariff</td>
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<tr>
<td>RH</td>
<td>Relative Humidity</td>
</tr>
<tr>
<td>SABS</td>
<td>South African Bureau of Standards</td>
</tr>
<tr>
<td>SANS</td>
<td>South African National Standard</td>
</tr>
<tr>
<td>SIP</td>
<td>Structural Insulated Panel</td>
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<tr>
<td>tCO₂e</td>
<td>tons of Carbon Dioxide equivalent</td>
</tr>
<tr>
<td>TIASA</td>
<td>Thermal Insulation Association of South Africa</td>
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<tr>
<td>TJ</td>
<td>Terajoule</td>
</tr>
<tr>
<td>UFAD</td>
<td>Under Floor Air Distribution</td>
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<tr>
<td>UPS</td>
<td>Uninterrupted Power Supply</td>
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<tr>
<td>U-value</td>
<td>Ability to transfer heat value</td>
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<tr>
<td>VAV</td>
<td>Variable Air Volume</td>
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<tr>
<td>VAWT</td>
<td>Vertical Axis Wind Turbine</td>
</tr>
<tr>
<td>VSD</td>
<td>Variable Speed Drive</td>
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<tr>
<td>W</td>
<td>Watt</td>
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<tr>
<td>W.m⁻¹.K⁻¹</td>
<td>Watts per meter per degree Kelvin</td>
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</tbody>
</table>
Contact details:

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