Support to the Energy Sector Reform in Lesotho: Energy Efficiency Builder's Manual

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FOREWORD

The Kingdom of Lesotho is part of the global community which is faced with the challenge of increasing energy demand, rising cost of energy and climate change related to energy usage. The building sector in Lesotho which comprise of commercial and residential housing is one sector which uses energy and face the same stated challenges. As part of its response program, the Ministry of Local Government in collaboration with the Department of Energy and other relevant stakeholders in the building sector worked together to compile this Energy Efficiency Builder's Manual. The manual seeks to guide and support this sector in incorporating energy efficiency in the planning, design, construction and operation of buildings.

Through the efficient use of energy and the use of alternative energy sources including primarily solar thermal and solar PV systems, this should also result in social-economic improvements in the country through use of less energy for the same or better output, enhancing better in-door health conditions as well as reduction of greenhouse gases' emissions.

This initiative, is meant to assist among many others, the rural based communities that have always been victims of climate change extreme events that have caused vulnerable living and even deaths especially during the cold seasons.

The Manual would be used as a guide for policy makers, local authorities, and key players in this sector which include property owners, property developers, architects and design, construction engineers and financiers.

Ministry of Natural Resources

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LIST OF ACRONYMS

AfDB	African Development Bank
BREEAM	Building Research Establishment Environmental Assessment Method
DME	Department of Minerals and Energy
EPC	Energy Performance Certificate
ER	Energy Rating
GBCSA	Green Building Council SA
GRI	Global Reporting Initiative
HVAC	Heat Ventilation & Air Condition
IEQ	Indoor Environmental Quality
LPG	Liquified Petroleum Gas
PV	Photovoltaic
PVC	polyvinyl chloride
SABS	South African Bureau of Standards
SANS	South African National Standard
SEFA	Sustainable Energy Fund for Africa
UNSDG	United Nations Sustainable Development Goals
UV	Ultraviolet

1. INTRODUCTION

The Ministry of Local Government with support from the Ministry of Energy and Meteorology has developed this Energy Efficiency Builder's Manual to guide and support in the development and maintenance of energy efficient buildings in the Kingdom of Lesotho. The manual applies to new and existing residential and commercial buildings.

An energy efficient building provides comfortable living conditions with optimal use of energy and other natural resources for the same or better level of comfort. The use of renewable energy sources would be even more advantageous from their clean status standpoint and at some point, some revenues may be generated from carbon trading.

The building sector in Lesotho which comprises of residential houses and commercial buildings, does significantly contribute to energy consumption. This energy consumption will surely increase as: the population increases; there is migration from lower energy-consuming rural areas to and semi-urban centres and there are improvements in living standards. Naturally, these changes will require modern and newer housing as well as commercial buildings for office and industrial activities.

The current average yearly population growth rate is 0.8%. The urban population was 31.5% of total population (2020) and this is projected to reach 57.7% of total population by 2050. These urban population figures translate to 674,092 people (2020) and 1,484,831 people (2050).

The National Sustainable Energy Strategy, October 2017, states that Lesotho's energy balance is dominated by biomass energy, which contributes 66% to the energy mix. The remaining 34% is made up of petroleum products, hydroelectricity, coal and LPG in order of decreasing magnitude. The energy balance is as follows: Electricity (6%), LPG (2%), Coal (4%), Petroleum (22%) and biomass (66%).

From the climate change scenarios of Lesotho, analysis of data confirms that there has been changes in the climate. Temperatures are increasing; frequency of cold temperatures is decreasing while that of hot temperatures is increasing. Precipitation is becoming more erratic with increasing occurrence of droughts and heavy rainfall. All these developments have an impact on energy usage in buildings.

Because of its altitude, Lesotho remains cooler throughout the year than most other regions at the same latitude. Lesotho has a temperate climate, with hot summers and cold winters. Maseru, the capital city, and its surrounding lowlands and often reach 30°C temperatures in the summer and winter temperatures getting down to −7°C while the Lesotho highlands temperatures can drop to −20 °C.

The variation in geomorphology and topography including the micro-climatological influences have significant impact on the ecology of a region. These factors characterize the formation of distinct ecological zones in Lesotho, and these are the **Lowlands**, the **Foothills**, the **Highlands** and the **Senqu River Valley**.

An understanding of the climate[1] enables building designers to design, construct and maintain buildings that respond and work within this climate to create an energy efficient and comfortable living environment. The Lesotho Meteorological Services provide more details which should all stakeholders in this process.

When buying, building, or renovating a residential or commercial building, it is important to consider both the current and predicted future climate of the particular zone. Good planning ensures that the building remains energy efficient and comfortable during its lifespan.

It is in this context of changing parameters of projected increase in energy demand and energy costs, climate change and technological changes that this Energy Efficiency Builders Manual forms part of the response and adaptation and program.

The Manual is aimed at involving a number of stakeholders including proper Policy Makers, Local Authorities (Councils) , Architects, Designers, Planners and Property Developers. The Ministry will follow this with enabling legal framework which responds to both local and international contexts including legal and regulatory practices and trends.

The Manual is based on national practical experiences and lessons from other countries. It is a Guide which should be used in conjunction with other Building Codes covering materials and equipment standards. The topics covered in this Energy Efficiency Builder's Manual include:

Efficiency Builders' Manual cover the following thematic areas;

- Motivation for an energy efficiency manual: the factors driving the need for an energy efficiency manual responding to aspects like the rising energy costs, finite natural resources and changing legal and technological environment.
- Bioclimatic architecture which refers to the design of buildings and spaces based on local climate. The aim is to provide thermal and visual comfort, while utilising solar energy and other environmental sources.

[1] https://www.lesmet.org.ls/home/open/Climate-of-Lesotho

- High performing building envelope: adequate insulation, high performing glazing and windows, air-sealed construction, and avoidance of thermal bridges. This aims at maintaining internal comfort conditions with minimum energy consumption.
- High performance active systems: Active design strategies use purchased energy including electricity to keep buildings comfortable. These design strategies include mechanical system components such as air-conditioning, heat pumps, radiant heating, heat recovery ventilators appliances and electric lighting.
- Maintenance & performance certification: Includes inspecting, repairing, and maintaining electrical systems, heating and air conditioning systems, and other utility services. Performance Certification - energy rating for a building based on the performance potential of the building itself and its associated active systems.

This Energy Efficiency Builder's Manual applies to existing and new residential and commercial buildings.

2. REGULATORY FRAMEWORK

This section provides an overview of the proposed regulatory framework necessary for the design, construction, and operation of energy efficient buildings. To successfully establish sustainable energy efficiency in buildings requires the collaboration of all relevant stakeholders.

These stakeholders include:

- Property developers & financiers', architects, builders, engineers.
- Standard Institute of Lesotho (functions to cover quality assurance)
- Non-governmental (e.g. Habitat for Humanity), Universities and research institutes
- Professional Associations
- Government Ministries
- Construction industry associations

A conducive legal framework with appropriate incentives will include;

2.1 Compliance & Enforcement Framework

The minimum energy efficiency requirements required in the design, construction and maintenance of buildings should be included in the existing building codes as well as building materials and equipment standards. The Ministry shall update relevant regulations and Acts to conform with the recommendations of this Energy Efficiency Builder's Manual. Some of these include the Building Control Act, 1995 which needs updating to incorporate energy efficiency requirements, covering, for example, requirements for energy efficient building materials, training of inspectors for compliance.

2.2 Materials for Construction and Operation

Energy efficient building materials are a critical part of the success of implementing energy efficiency in the building sector. These materials include insulating concrete foams, plant-based polyurethane foam, straw bales, structural insulated panels, concrete and clay bricks, stone masonry, plastic composite, lumber, low-e windows, vacuum insulation panels and soils. Most of these materials are readily available.

The policy makers will work with research and development institutes at universities and quality control bodies to develop the acceptable minimum efficiency standards for building materials.. Government shall provide support or incentives for the local manufacture of these products is needed to promote this industry. Valuable lessons can be derived from the current policies such as the equipment / appliance labelling should be part of this program.

2.3 Skills Base - Design, Construction and Operation

The Ministry of Local Government, in conjunction with the Ministry of Energy will take to take the lead in facilitating the development of the requisite skills base critical in the design, construction and operation of energy efficient buildings. This includes skills in energy efficient materials, energy efficient equipment, energy audits and compliance inspections.

2.4 Demand for Energy Efficient Buildings

Based on projected population growth, rural to urban migration, increasing energy costs and climate change impact, it is anticipated that a combination of these factors would trigger a demand for energy efficient buildings. This energy efficiency manual is a tool which can be used to meet these requirements. The Ministry of Local Government will ensure that all buildings have minimum energy performance ratings.

2.5 Access to Finance

Access to affordable financing instruments is important for a successful promotion of energy efficient buildings. The experiences of Solar PV funding from African Development Bank (AfDB) - managed Sustainable Energy Fund for Africa (SEFA) may be used as a model. A national fund to be hosted and managed by the Ministry of Local Government may be introduced to mobilize financing for this purpose specially to cater for rural based housing.

3. SITE SELECTION

3.1 Location

The location where a building is to be constructed and the environment surrounding the location play an important role in the overall sustainability of the green building. The building must satisfy the local municipality requirements, environmental regulations (Environmental Impact Assessments) and also a blend into surrounding natural ecosystem with minimal negative impact on it. Some of the important parameters to consider while selecting the site for construction are:

- Impact on the environment
- Connection with the community
- Transportation
- Public amenities and availability
- Utilizing open spaces (provided that they are not green lungs in urban areas)
- Storm water control

Sites for new buildings should be chosen where transport energy consumption can be minimised. The table below indicates the range in energy consumption for different modes of transport.

Table 1: Energy consumed per kilometre for different types of transportation

Type of transport	Litres of fuel, or energy equivalent, consumedper person to travel 100 km
Car (single occupant)	9.00
Car (2 occupants)	4.50
Taxi (12 passengers)	1.00
Bus	0.70
Walking	1.00
Cycling	0.36
Design Guidelines for Energy Efficient Buildings in Johannesburg. City of Joburg, Gauge, CSIR 2008	

The ideal sites are where occupants can walk or cycle to the building; near public transport nodes such as taxi ranks or bus stops

3.2 Existing Buildings / Brownfields

A brownfield site is one that carries constraints related to the current state of the site. The site might be contaminated or have existing structures that architects have to tear down or modify in some way before the project can move forward.

Greening existing buildings is an approach to apply the principles of green building to old and existing buildings with environment responsive and energy efficient 'green features' or devices, e.g. through retrofitting. It allows considerable reduction of energy consumption and greenhouse gas emission.

Some other advantages of greenfield projects include the following:

- Encourage good environmental stewardship. Turning brownfield spaces that no one wants into greenfield sites that inspire communities can prevent sprawl and ensure that these areas don't go to waste.
- Use existing systems. Sewer and water systems are often still in good working order or salvageable, which can save planners time and money.
- Keep costs down. Brownfield sites are typically less expensive to purchase because they require more work to transform and meet state and local requirements. When renovation costs are also kept low, additional cost savings could result.
- Encourage urban renewal projects. Most brownfield sites are located in past industrial areas, in close vicinity to city centres, making them ideal for required urban expansion or infill without sprawl.

3.3 Greenfields Site

A brownfield site is one that carries constraints related to the current state of the site. The site might be contaminated or have existing structures that architects have to tear down or modify in some way before the project can move forward.

Some other advantages of greenfield projects include the following:

- Increased ease of compliance with environmental and sustainability standards. It will be easier to create an environmentally conscientious space when you don't have to focus your time, efforts, and money on decontaminating the area.
- More opportunity to design community-focused projects. Greenfield sites are typically located in residential or suburban areas. These locations are perfect for building schools, healthcare facilities, and civic centres that community members can easily access.

3.4 Building orientation

Building orientation refers to the compass direction the building faces. In general, the rooms where people spend most of their time should be orientated towards true north not the magnetic north). A building's orientation is an important step in providing the structure with thermal and visual comfort. Depending on topography, the visual comfort can also be in other directions. Both the building's size and orientation should be decided early on in the design process, as one cannot be optimized without the other.

Figure 1: Building orientation

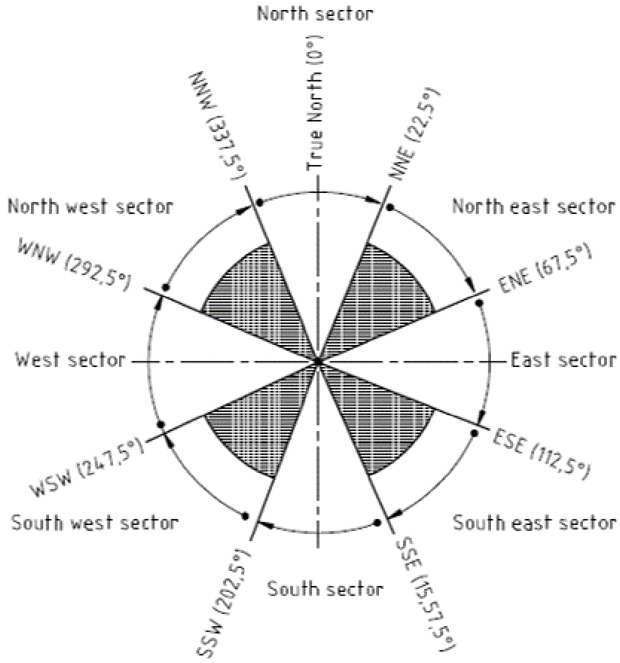
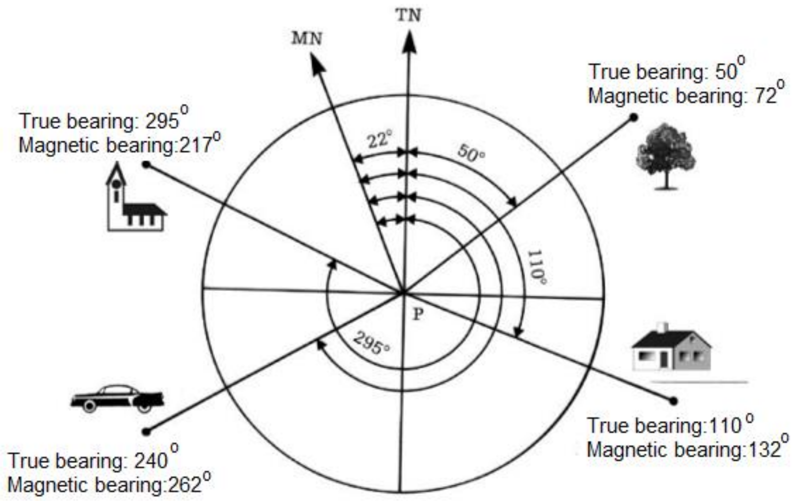


Figure 2: Relationship Between True North & Magnetic North



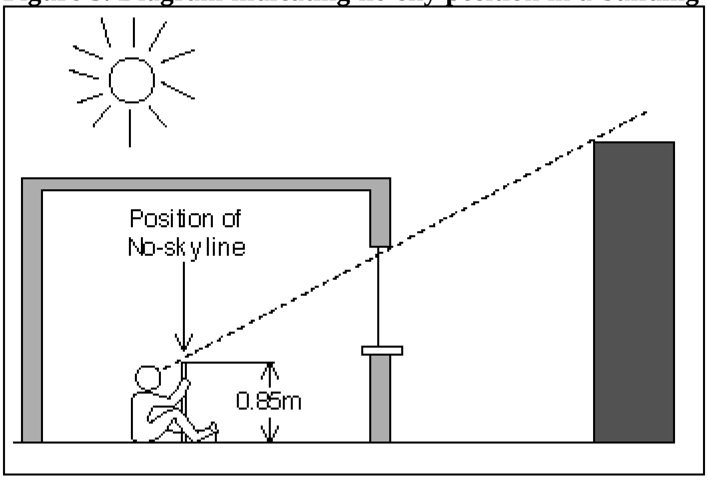
A good design orientation for a building helps lower its total energy usage. A building's orientation in cold areas is much different than hot climate areas. In cold areas, it is important to utilize the sun as much as possible to help with heating the building. This way, the building won't have to use too much electricity to keep the occupants warm during the cold months.

The largest surface of the building will need to be exposed to the sun's rays. The more surface area exposed to the sun's path, the more the sun can passively heat the building.

3.5 Access to light

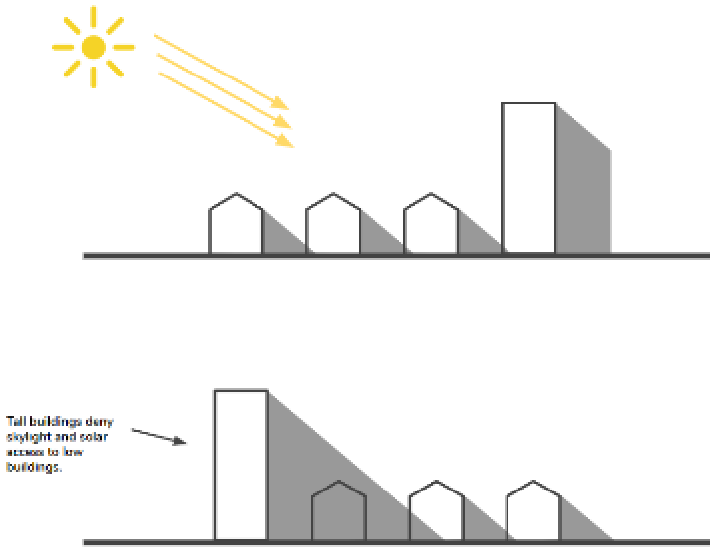
Buildings should be arranged on site to ensure that they have good access to daylight and do not shade close neighbours. Obstructions in front of windows can severely reduce the quality of daylight in spaces. The quality of daylight in a space relates to the visible sky angle measured from the centre of a window on an external wall. The larger this angle the better the daylight quality will be in the space. The no skyline position is the location on the working plan (0.85m above floor in residential and 0.7m above floor level in offices) where the sky can no longer be seen. Space to the interior of this will usually requires supplementary electrical lighting.

Figure 5. Diagram indicating no-sky position in a building



3.6 Access to sunlight

Daylighting is the controlled admission of natural light, direct sunlight, and diffused skylight into a building to reduce electric lighting and saving energy. By providing a direct link to the dynamic and perpetually evolving patterns of outdoor illumination, daylighting helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs.

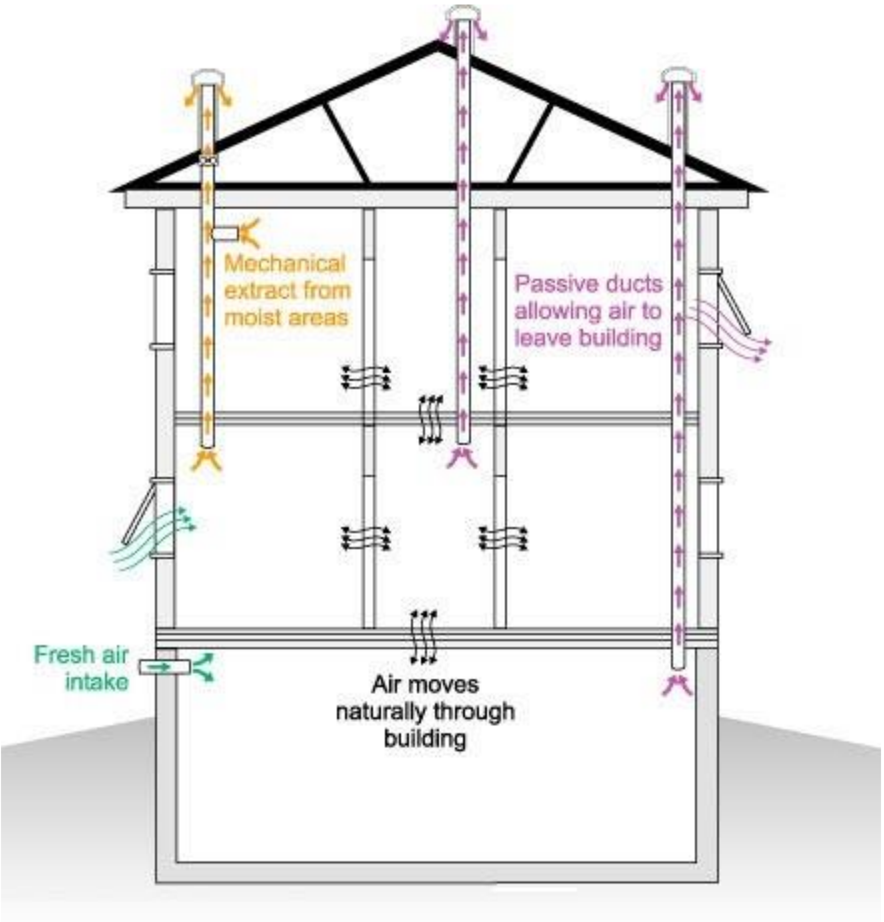


https://planlux.net/planning-for-solar-access-building-orientation/

3.7 Access to ventilation

The layout of buildings on site and the landscaping strategy should ensure that buildings have good access to breezes where this is required to cool and ventilate buildings. Landscaping can also be used to provide windbreaks to create comfortable protected external spaces and reduce heat losses from buildings in winter.

Figure 3: Natural ventilation system



https://www.hourigan.group/

3.8 Access to facilities

Locating facilities such as cafes, restaurants, post boxes, schools, banking and retail outlets within or near residential areas or places of work support energy efficiency by enabling people to walk to these facilities rather than use their cars.

4. GREEN BUILDING DESIGN

4.1 General

A green building is a building that, in its design, construction or operation, reduces or eliminates negative environmental impacts. Green buildings preserve precious natural resources and improve the quality of life. Features that make a building ''green'' include:

- Efficient use of energy, water and other resources
- Use of renewable energy, e.g. solar energy for water heating and electricity generation
- Pollution and waste reduction measures, and the enabling of re-use and recycling
- Good indoor environmental air quality
- Use of materials that are non-toxic, ethical and sustainable
- Consideration of the environment in design, construction and operation
- Consideration of the quality of life of occupants in design, construction and operation
- A design that enables adaptation to a changing environment

4.2 What is bioclimatic architecture

Bioclimatic architecture[2] is a way of designing buildings based on the local climate with the aim of ensuring thermal comfort using minimum environmental resources. The buildings should also blend into their natural surroundings. This kind of architecture is based on achieving some control of heat gains and losses from a building resulting from the climate and thus optimise environmental conditions within.

Bioclimatic design is the foundation for an energy efficient building. A noticeable feature of such buildings is their optimised orientation and incorporation of solar protection. The main aims of bioclimatic architecture are to create healthy, comfortable buildings for the inhabitants of these buildings, while respecting the environment. To do this, it is essential to avoid using polluting materials, ensure the wellbeing of local biodiversity and make efficient use of energy, building materials, water and other resources.

4.2.1 Bioclimatic strategies in architecture

Bioclimatic buildings are based on design and daily use strategies that contribute to reducing their energy costs.

[2] https://www.iberdrola.com/about-us

The following are the features to consider in the design of new buildings or renovation of old buildings. These are the most common:

- Efficient design. Designing buildings that adapt to the local climate to minimise energy expenditure and resources used, avoiding leaks and wastage.
- Control and smart use of space. Buildings and their rooms should be of a suitable size as to optimise energy use (specifics in building codes).
- Sustainable materials. Sustainable materials like wood, stone, natural fibre and recycled materials minimise the impact of the building (a lot can be adapted from traditional houses).
- Renewable energies. primarily solar thermal (water heating) and solar PV (generating electricity)

4.2.2 Main elements of bioclimatic design

Bioclimatic buildings require the use of a series of elements and building techniques that help to reduce their energy consumption and environmental impact:

- The orientation, size, height, layout, and the colour of the buildings is planned before they are built to make the best use of energy.
- Buildings are kept compact to reduce their surface area, with the main windows facing sun direction to make the most of passive solar energy.
- The materials surrounding the outside of the buildings (walls, doors, roofs, etc.) must be properly insulated to avoid heat loss through heat transfer.
- Ventilation systems ensure that the heat in the air that is removed from the building is transferred to the fresh air that is brought in through heat exchangers to avoid thermal losses
- Use of renewable energy as source for thermal and electrical energy

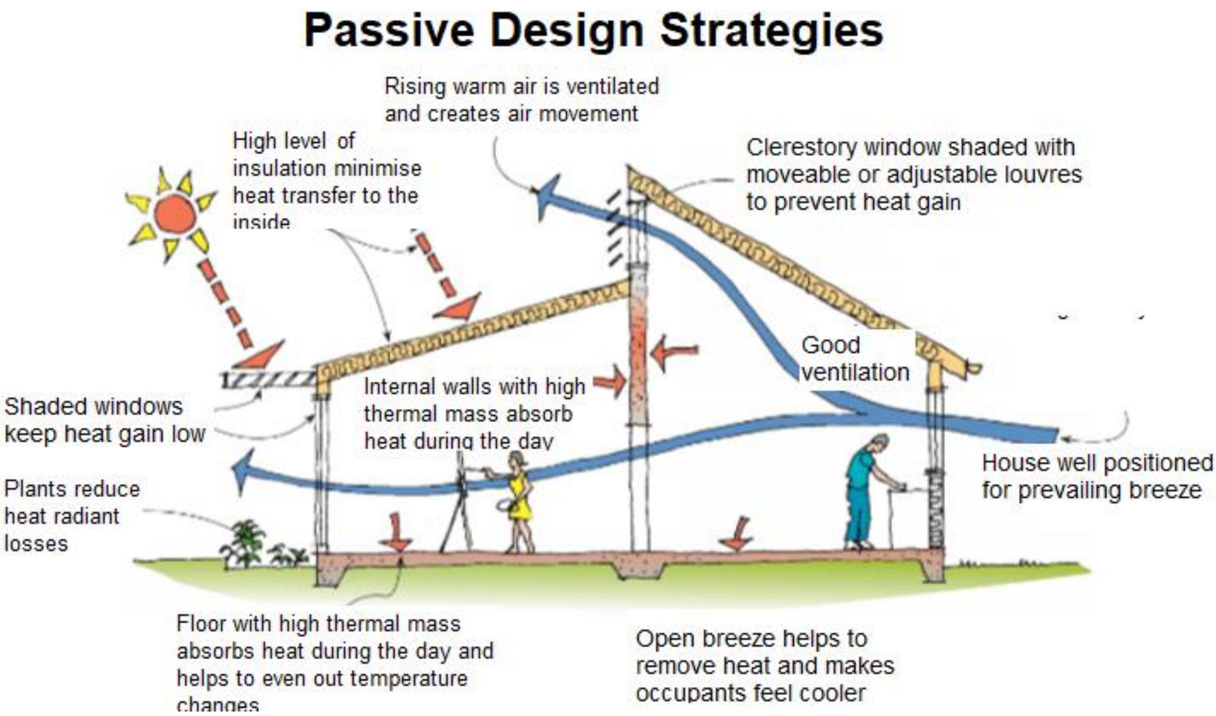
These elements and techniques are discussed in the following sections.

4.3 Passive Design

Passive design is design which responds to local climate and site conditions to optimise building users' comfort and health while minimising energy use. This is achieved by using free, renewable sources of energy such as the sun for heating, cooling, ventilation and lighting, thereby reducing or removing the need for mechanical heating or cooling. Using passive design can reduce temperature fluctuations, improve indoor air quality.

Good passive design should reduce or eliminate the need for additional heating or cooling depending on climatic zone. Approximately 25 to 35% of building energy is used for heating and cooling. This could be significantly reduced through effective, climate-appropriate design which includes improvements in buildings materials and energy efficient technologies.

Figure 4: Passive design strategies



Source: https://archi-monarch.com/

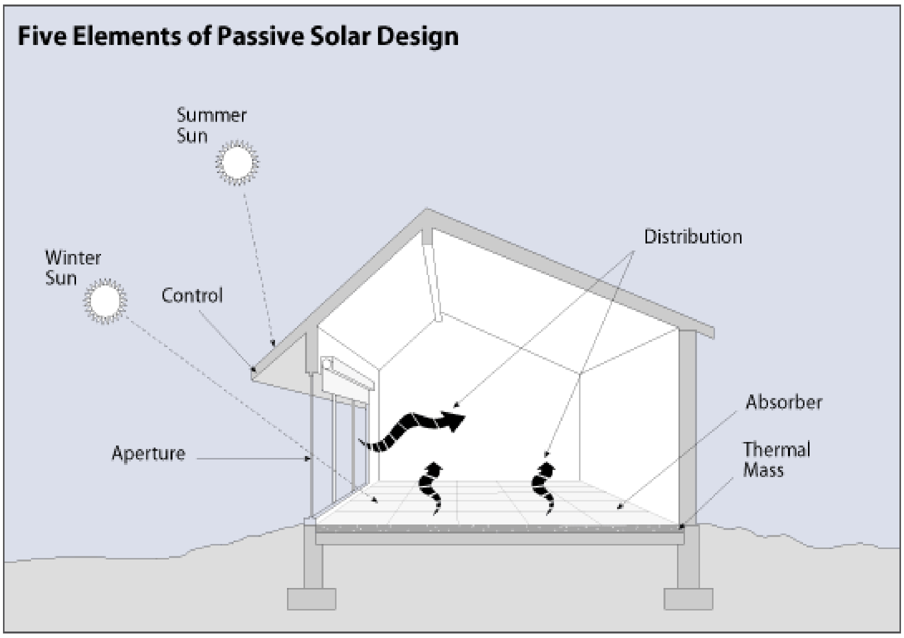
4.3.1 Passive heating

Passive solar heating makes use of the building components to collect, store, and distribute solar heat gains to reduce the demand for space heating. It does not require the use of mechanical equipment because the heat flow is by natural means and the thermal storage is in the structure itself. Also, passive solar heating strategies provide opportunities for daylighting. It is best to incorporate passive solar heating into a building during the initial design.

The main elements of passive heating include:

- Letting the sun in to the building - solar radiation travels through glass areas exposed to full sun. Window orientation, shading, frames and glazing type affects how well this process works.
- Storing the sun's heat inside the building - trapped heat is absorbed and stored by materials with high thermal mass inside the building. This heat is released at night when the building starts to cool down.
- Ensuring good heat distribution - heat released from thermal mass is distributed to where it is needed through good design of air flow and convection.
- Ensuring that heat is not lost - appropriate building shape and room layout will reduce heat loss. Heat loss occurs from all parts of the building, but mostly through the roof. In cool and cold climates, compact building shapes that minimise roof and external wall area are more efficient. Heat loss is further minimised with appropriate choice of windows and curtains or blinds, and well-insulated walls, ceilings and floors.
- Ensuring that cold air does not enter your home - infiltration of cold air is minimised with airlocks, draught sealing, airtight construction detailing and high-quality windows and doors.

Figure 5: Five (5) Elements of Passive Solar Design



Source: https://www.energy.gov/eere/office-energy-efficiency-renewable-energy

4.3.2 Passive heating principles

4.3.2.1 Greenhouse principles

Passive heating design relies on greenhouse principles to trap solar radiation. Heat is gained when shortwave radiation from the sun passes through glass, where it is absorbed by building elements and furnishings and re-radiated as longwave radiation. Longwave radiation cannot pass back through glass as easily as shortwave radiation, so the temperature inside the room increases.

4.3.2.2 Thermal mass and thermal lag

Thermal mass describes the ability of a material to absorb, store and release heat energy. Thermal mass can be used to even-out variations in internal and external conditions, absorbing heat as temperatures rise and releasing it as they fall. In building design, this can be useful to even-out and delay extremes in thermal conditions, stabilising the internal environment and so reducing the demand for building services systems.

Thermal lag is the rate at which a material releases stored heat. For most common building materials, the higher the thermal mass, the longer the thermal lag. These are typically heavyweight construction materials like concrete, brick and stone.

Table 2: Relative thermal lag of some common building materials

Material	Thickness (mm)	Time lag (Hours)
Double brick	220	6.2
Concrete	250	6.9
Autoclaved aerated concrete (AAC)	200	7.0
Adobe	250	9.2
Rammed earth	250	10.3
Compressed earth blocks	250	10.5
Sandy loam	1,000	30
https://archi-monarch.com/		

4.3.2.3 Heat flow

Heat is lost through building elements (walls, floors, ceilings, windows) by conduction, during the night when the outside temperature is lower than the inside temperature. Heat flow through any building material is directly proportional to the temperature difference on either side of that material. This is called the temperature differential (also referred to as delta T or ΔT). The greater the temperature differential, the greater the heat flow through the element.

- The heat flow through different materials varies depending on their insulation properties (R value). Heat flow through windows(glass) is much higher because they usually have the lowest R value of any construction material. Because hot air rises, air temperatures stratify in a building, with the hottest air in the highest areas. This means that the temperature differential to the outside will be largest in those highest areas, and you may lose more heat through those areas.
- Preventing heat loss is an essential component of efficient building design in any climate. It is even more critical in passive heating design because the main heat source is only available during the day. The building fabric must retain energy collected during the day for up to 16 hours and longer in cloudy weather.

Table 3: R-Values for different materials

R-Values of Common Building Materials	
Material	**R-value per cm of material**
Air	**3.66**
Fiberglass (batt)	**8.03**
Fiberglass (blown)	**5.59**
Cellulose (blown)	**9.32**
Rock wool (batt)	**8.59**
Rock wool (blown)	**6.99**
Vermiculite	**5.59**
Perlite	**6.99**
Wood (pine)	**3.25**
Wallboard	**2.54**
Brick	**0.28**
Glass	**18.29**
Additional source of info. https://efficiencymatrix.com/building-material-r-values/	

4.3.3 Orientation for passive heating

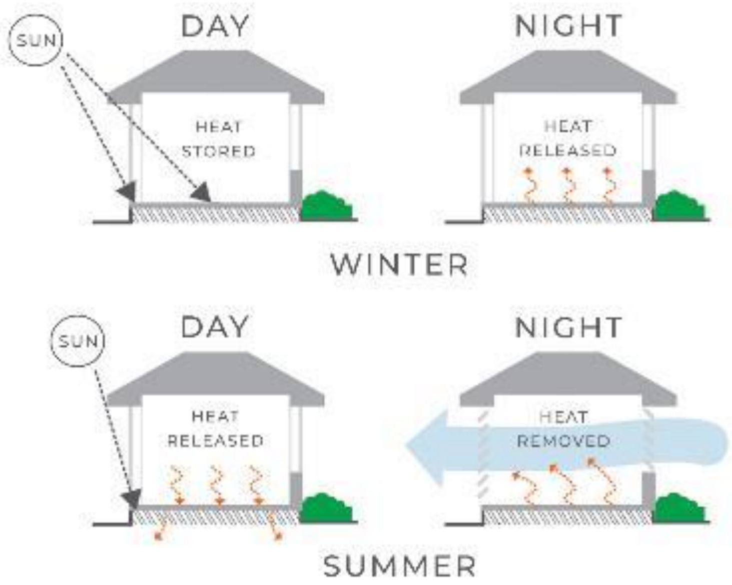
For best passive heating performance, daytime living areas should face north. Ideal orientation is true north, but orientations of ±15º of north still allow good passive solar gain.

Where solar access is limited (for example, if the sun is blocked by nearby buildings or other houses, as is often the case in urban areas), you can still have an energy-efficient building through careful design.

4.3.4 Thermal mass for passive heating

Thermal mass is the capacity of a material to store heat energy. Thermal mass reduces temperature fluctuations by absorbing heat when the ambient temperature is hotter than the mass, and then releasing the heat when the ambient temperature falls below the temperature of the mass. When used effectively, this results in improving indoor comfort and reduce heating energy costs.

Figure 6: Thermal mass



https://acarchitects.biz/

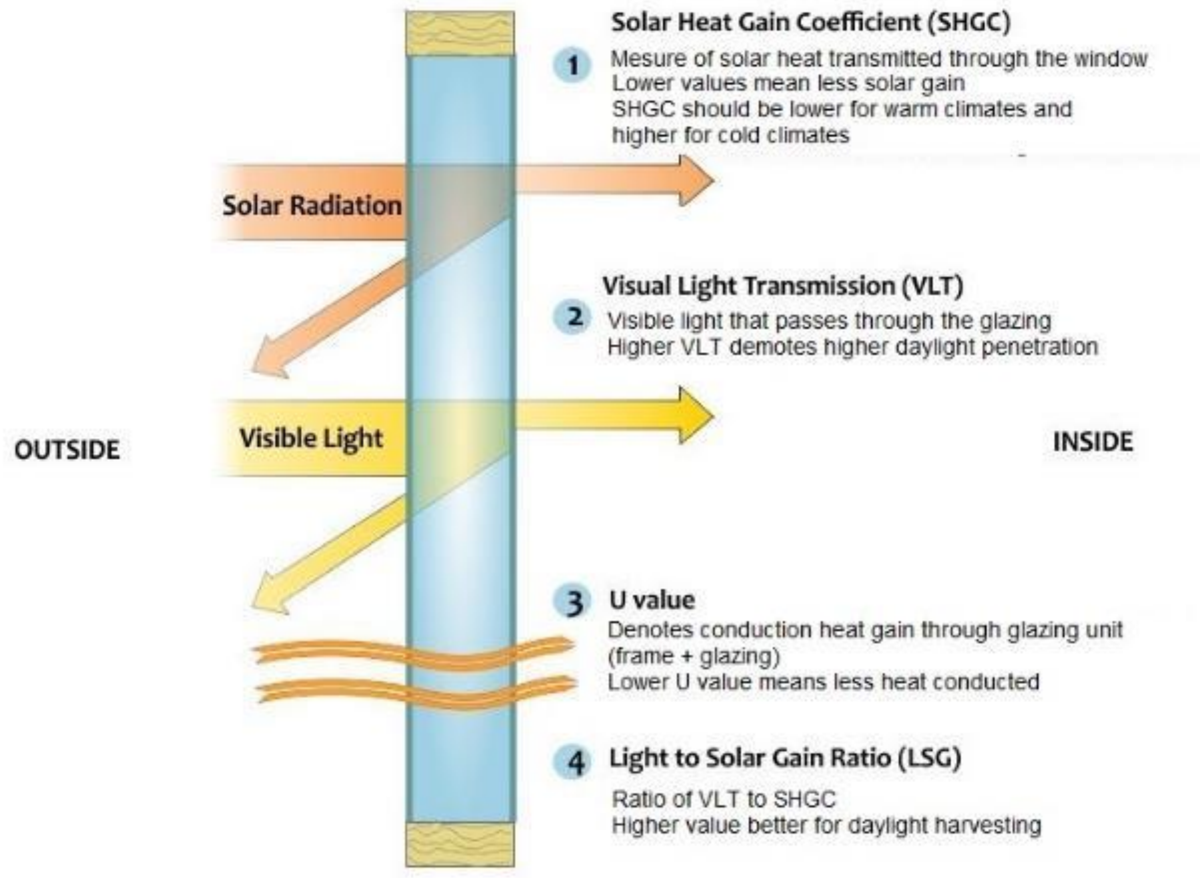
- Locate thermal mass where it will be exposed to direct solar radiation or radiant heat sources.
- Because thermal mass absorbs radiant heat as well as solar radiation, locating thermal mass walls between north-facing living areas and south-facing sleeping areas is a good idea. These will radiate daytime solar gains into sleeping areas at night through thermal lag, as well as providing a barrier to noise.
- Air movement within the house heats or cools thermal mass. Locate the mass away from cold draught sources and expose it to convective warm air movement in the building.
- Good thermal mass storage includes insulated or internal suspended slabs that are not earth-coupled, masonry walls, water-filled containers and newer phase-change materials.

4.3.5 Windows and glazing for passive heating

Glazing and glazing units should be designed to admit light while controlling heat gain and heat loss into the building. Glazing is where most heat is lost and gained, because it transfers both radiant and conducted heat.

When designing glazing, the type and windows size has to balance daytime heat gain against night-time heat loss. Large windows can facilitate solar gain, but they also lose significant amounts of heat at night. Window frames also conduct heat. Timber, PVC or thermally separated metal window frames in cooler climatic zones and hotter climatic zones where air-conditioning is used to prevent heat transfer should be used.

Figure 7: Glazing Properties for daylight harvesting and energy efficiency



https://fairconditioning.org/

4.3.6 Glass-to-mass ratios

In designing a direct gain passive solar building, there should be a balance between the amount of glazing on each side of the building and the amount of thermal mass available inside to store and later release heat. Getting the glass-to-mass ratio wrong will result in too much or too little heating.

The building codes should be used (outdated 1989 Development Control Code), the basic rule "the 7% rule" states that the first 7% of the glazing in a direct gain passive solar building is covered by the incidental thermal mass in the building. In other words, if your solar windows' surface area equals 7% of the total floor surface area of the building, you do not need to include any extra thermal mass.

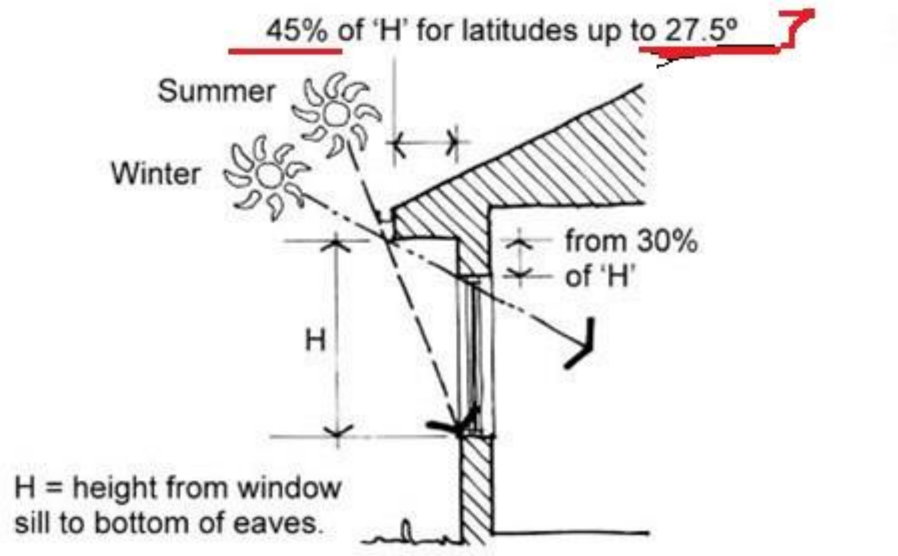
The amount of thermal mass used should be proportional to the day–night (diurnal) temperature range. The area of north-facing glass with solar access should range between 15% (for temperate climates) and 25% of the area of exposed thermal mass in a room.

4.3.7 Shading for passive heating

Passive heating should be used together with appropriate shading of windows to allow maximum winter solar gain and prevent summer overheating. This is most simply achieved with northerly orientation of appropriate areas of glass and well-designed eave overhangs.

Fixed horizontal shading, such as eaves, blocks summer sun but allows the sun in winter. Fixed shading devices can regulate solar access to north-facing glass throughout the year, without requiring any effort. Correctly designed eaves are the simplest and least expensive shading method for northern elevations.

Figure 8: Fixed shading – Passive Heating



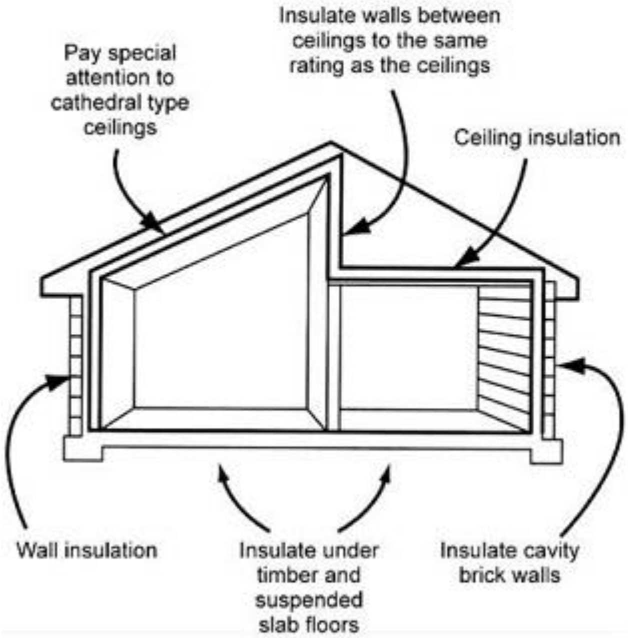
4.3.8 Floor planning for passive heating

Bedroom and lounge areas should be in the north facing side. Kitchen and bathrooms are not always occupied and should be on the other side. In general, living areas should be placed along the north side of the home. Ceramics are recommended for the kitchens and bathrooms while lounge and bedrooms should have flooring with higher thermal mass.

4.3.9 Insulation for passive heating

High insulation levels are essential in passive solar houses. Try to insulate above the minimum levels required by the Building Codes . Consider insulation for all relevant housing elements:

- Ceilings and roof spaces account for 25–35% of winter heat loss. To prevent heat loss, place most of the insulation next to the ceiling because this is where the greatest temperature control is required.
- Floors account for 10–20% of winter heat loss. In cool climates, insulate the underside of suspended timber floors and suspended concrete slabs. Insulate the edges of ground slabs.
- Walls account for 15–25% of winter heat loss. Insulation levels in walls are often limited by cavity or frame width. In cold climates, alternative wall construction systems that allow higher insulation levels are recommended.



4.3.10 Sealing your building for passive heating

While no building should be completely sealed to air flow, reducing the amount of warm air escaping to the outside can improve energy efficiency. Air leakage accounts for 15–25% of winter heat loss in buildings. Reduce air leakage in your building by:

- choosing high-quality windows and doors with airtight seals
- using airtight construction detailing, particularly at wall−ceiling and wall−floor junctions
- avoiding downlights that penetrate ceiling insulation
- avoiding open fires, and fitting dampers to chimneys and flues or blocking them off if unused
- avoiding permanently ventilated skylights
- ducting exhaust fans and installing nonreturn baffles
- sealing gaps between the window and door frames and the wall before fitting architraves in new homes and additions
- improving the performance of existing windows and doors by using draught-proofing strips. Install these between the door and frame, at the door base and between the openable sash of the window and the frame.

- sealing air vents; use windows and doors for ventilation as required. However, this may not be advisable for homes with unflued gas heaters.

4.4 Passive cooling

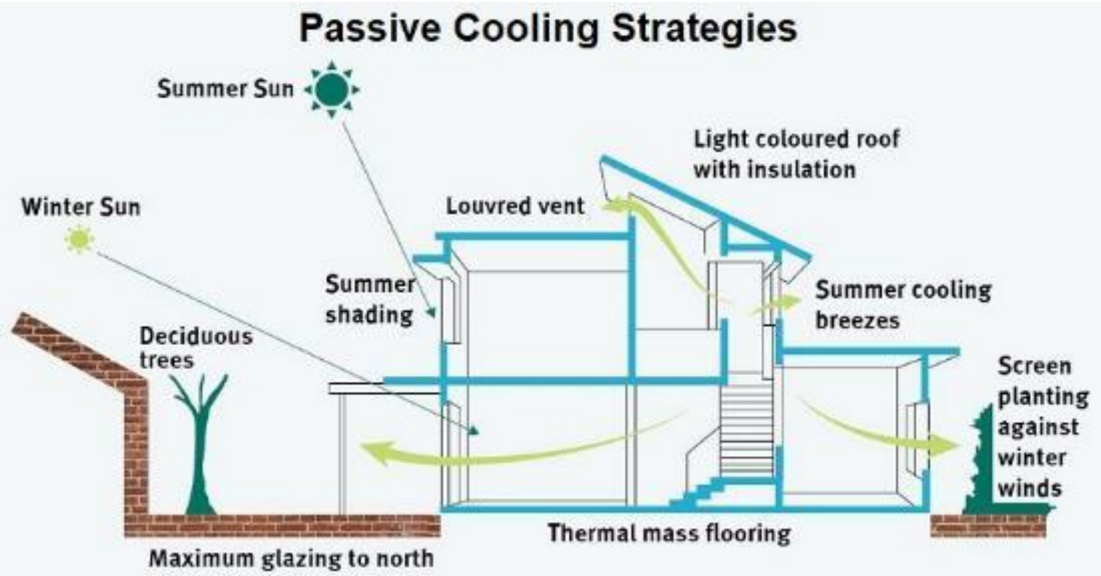
Passive cooling is an approach that focuses on providing thermal comfort by controlling heat gains and heat dissipation without involving mechanical or electrical devices. There are 2 basic components to passive cooling: cooling the building, and cooling people.

Cooling buildings is about:

- reducing heat gain (for example, by installing insulation and shading windows, walls and roofs)
- increasing heat loss and access to cooling sources (for example, by using earth coupling and encouraging air movement).

Cooling people is about:

- physiological comfort (the physical factors necessary for comfort; for example, encouraging breezes to evaporate perspiration and increase body cooling)
- psychological comfort (psychological factors that affect our perception of comfort, for example, levels of acclimatisation and air movement, radiation and conduction).



http://www.sozo.ae/

4.4.1 Reducing heat gain

Heat gain is a temperature rise within a space due to heat from the sun (solar radiation), heat from surfaces (long wave infrared radiation), heat originating from other sources within the space (such as heating appliances, ovens, people, mechanical systems, lights and computers) and so on. It is the heat that is gained from such sources that changes the prevailing temperature within the space.

4.4.1.1 Thermal mass

Shade thermal mass in living areas during the day in summer, and avoid or limit thermal mass in sleeping areas. In designing the buildings, in climatic with little or no heating requirement, low mass is generally the preferred option.

4.4.1.2 Insulation

Insulation is critical to passive cooling requires minimum insulation levels for roofs, walls and floors, according to your climate zone and other building features. .

4.4.1.3 Shading of glazing

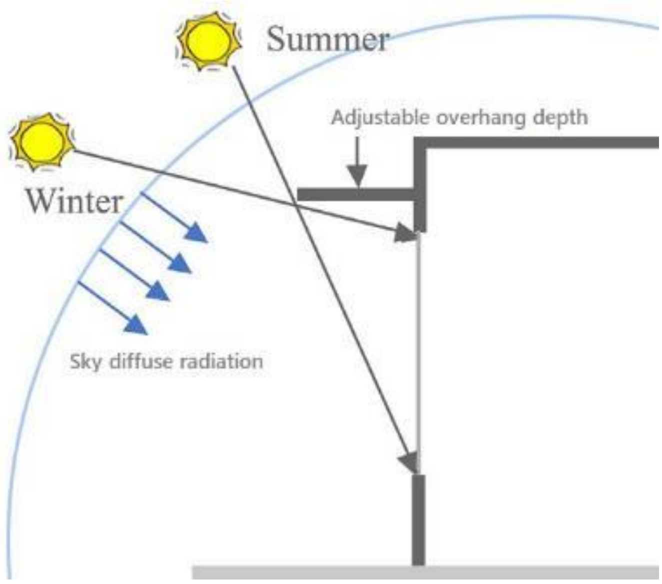
Shading of glazing is a critical element in passive cooling. Glazing is the main source of heat gain (through direct radiation and conduction), and of cooling (through cross, stack and fan-drawn ventilation; cool breeze access and night purging).

Choosing windows with good thermal performance (for example, double glazing) will reduce the heat gain caused by sun hitting the window. But preventing sun from hitting the window in the first place will have a much larger effect.

In most climates:

- use horizontal (for example, correctly sized eaves) or adjustable shading on north-facing windows to block high-angle summer sun and allow in winter sun (see figure below).
- use deep overhanging shading, or vertical shading if close to the window, for east- and west-facing glass.
- For hot humid climates, maximising shading for all aspects will be useful.

Figure 9: Adjustable overhang depth.



4.4.2 Cooling methods

4.4.2.1 Windows

Design windows to maximise beneficial cooling breezes by providing multiple flow paths and minimising potential barriers; single-depth rooms are ideal in warmer climates.

Wind does not actually 'blow' through a building — it is sucked towards areas of lower air pressure. To draw the breeze through the house, use larger opening areas on the leeward (low pressure or downwind) side of the house and smaller opening areas on the windward (high pressure or upwind) side. Openings near the centre of the high-pressure zone are more effective than openings on the edge because pressure is highest near the centre of the windward wall and diminishes toward the edges as the wind finds other ways to move around the building.

For breeze collection, window design is more important than orientation

- The design of openings to direct airflow inside the building. Size, type, external shading and position of any openings (doors and windows) is critical.
- Position windows (vertically and horizontally, see figure below) to direct airflow to the area where occupants spend most time (for example, dining table, lounge or bed)

Figure 10: Vertical & Horizontal Louvres

	
Vertical louvres	Horizontal louvres

4.5 Floors

4.5.1 Floors with underfloor heating

Heat is lost through the foundations and floor into the ground[3]. Floors with under floor heating should have insulation installed with an R-Value of 1 m².K/W. Heating elements can be installed above expanded or extruded polystyrene insulation. If the floor is not heated, it is more economical to insulate the foundation walls where heat loss is greatest. Expanded or extruded polystyrene can be used as under floor and perimeter insulation.

4.5.2 Insulating concrete slab

In new buildings, insulate under a concrete slab-on-ground by placing a continuous layer of 30 mm minimum, SD (Standard) grade expanded or extruded polystyrene (EPS/XPS) board over the damp-proof membrane before the slab is poured. It is essential to use perimeter insulation.

Slab perimeter insulation is more essential than the underside of the slab as most of the heat loss from the slab occurs at the edges between the air and the ground. Depending on the circumstances, combining under slab with slab edge insulation can result in thermal performance of the slab improving by 100% or more. Perimeter insulation can bring significant gains in energy efficiency. Much of the thermal performance improvement can be achieved with a perimeter insulation R-value of less than 1.0.

4.5.3 Acoustic floor

Often referred to as a ‘floating floor’, the high-density thin Rock Mineral Wool batt is used as a resilient layer providing acoustic insulation against impact noise. There are two prospective installation

[3] Thermal Insulation Products & Systems Association SA (www.tipsasa.co.za)

methods. The first option has a screed directly on top of the concrete intermediate floor slab, then the Rock Mineral Wool high density acoustic batt with a floor finish such as timber based decking or fibreboard sheeting. The second option is to place the Rock Mineral Wool high density acoustic batt directly onto the concrete intermediate flooring slab, overlay with a polythene sheet prior to finishing with a screed top layer.

5. BUILDING SEALING

5.1 Building envelope

The main purpose of the building envelope is minimizing heat transfer in both directions. Heat gain increases air conditioning costs during summer, while heat loss increases heating costs during winter. A well-designed thermal envelope reduces both heat flows, achieving energy savings during the lifespan of the building.

An efficient building envelope can reduce all forms of heat transfer effectively. Adequate insulation is important to reduce heat conduction through walls, rooftops and other building elements. The building must also have an airtight construction since air leaks can also carry heat through the envelope. The building must use fenestration that minimizes both heat conduction and solar heat gain.

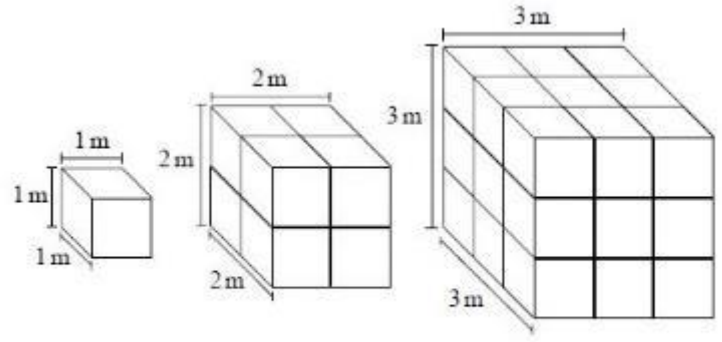
Insulation materials are characterized by their variety, adapting to various applications and building needs. In existing properties, insulation is often applied on surfaces and then covered with a finishing layer. Spray foam insulation is also a common option since it can be applied in hollow or hard-to-reach places. New constructions allow more freedom since insulation can be integrated with the structure.

5.2 Surface area to volume ratio

The surface area to volume ratio (S/V) is an important factor for the performance of a building. The greater the surface area, the greater the potential heat gain or loss through it. Consequently, a small S/V ratio implies minimum heat gain and heat loss. In order to minimise unwanted losses and gains through the structure of the building, it is desirable to design a compact shape.

The surface area to volume ratio is calculated by dividing the volume of the building (in m^3) by the surface area of the building (in m^2).

Figure 11: Diagram showing surface area to volume ratio - different blgd shapes



surface area	$6m^2$	$24m^2$	$54m^2$
volume	$1m^3$	$8m^3$	$27m^3$
surface area: volume	6:1	3:1	2:1

5.3 Direct solar gain

Direct solar gain is the most basic form of solar gain. Solar energy enters through north-facing glazing and is absorbed by thermal mass incorporated into the floor and walls. Heat is stored in the thermal mass during the day and later released during the night into the living space.

The heat collected by allowing sunlight to enter buildings then heat and warm high thermal mass areas like masonry walls or tiled floors. The thermal mass stores this heat and releases it gradually, keeping the building warm. The heat can also be avoided with reflective materials.

Direct solar gain is important for any site that needs heating because it is the simplest and least costly way of passively heating a building. Avoiding direct solar gain is also important in hot sunny climates. Good direct gain is measured or predicted by determining how much heat energy the sun delivers to the interior space throughout the day and year. More heat gain is desired in the winter and less is needed in the summer.

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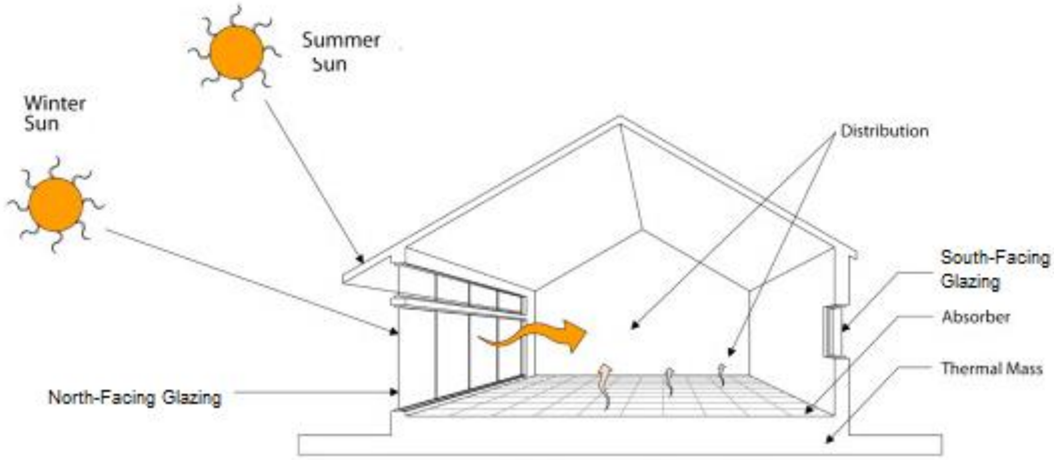
Figure 12: Direct solar gain



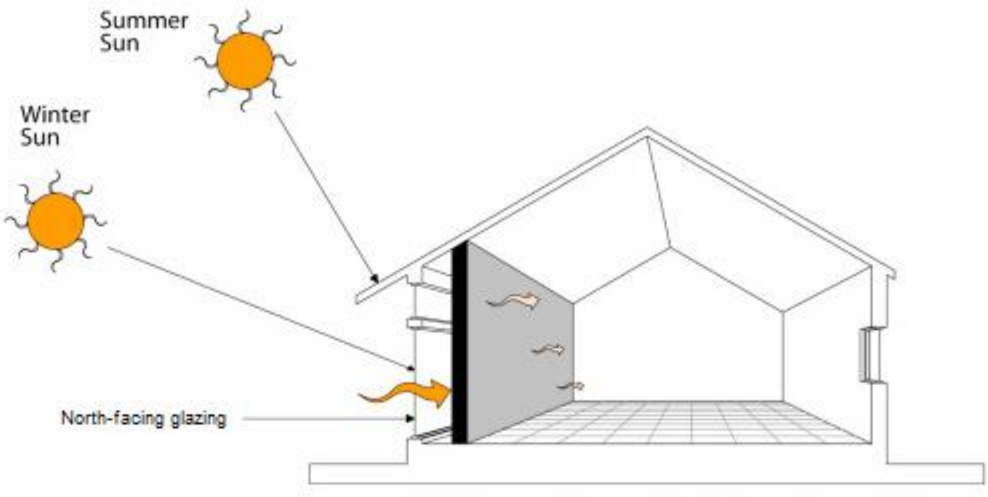
The following factors should be considered in harnessing solar gain:

- Location and orientation: Location and orientation of the building to ensure good solar access at the right times of the year.
- Building envelope: Openings, glazing (and possible blinds and curtains) in the building should be designed to direct solar access to the right area and retain heat gathered.
- Material and finishes: The location, colour and type of finishes should be selected to provide good thermal storage.

5.4 Indirect Gain (Trombe Wall)

An indirect-gain passive solar home has its thermal storage between the north-facing windows and the living spaces. The most common indirect-gain approach is a Trombe wall. These use the sun to warm high thermal mass materials such as rock or water. This heat is then stored and circulated to the building using air or water as a medium.

Figure 13: Indirect Gain (Trombe Wall)



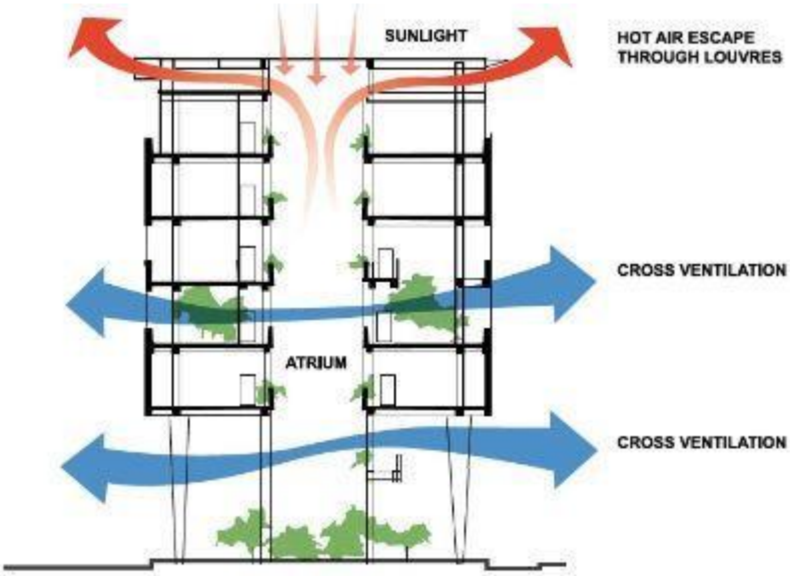
These systems can be complex to design and key considerations include:

- Location: Location of the indirect system to ensure that is near the building and has good solar access.
- Sizing: The collection area, thermal storage capacity and heat circulating system needs to be sized correctly.

5.5 Cross ventilation

Cross ventilation is a natural and energy efficient method of cooling. The system relies on wind to force cool exterior air into the building through an inlet (like a wall louver, a gable, or an open window) while outlet forces warm interior air outside (through a roof vent or higher window opening).

Figure 14: Cross ventilation in a building



https://za.pinterest.com/pin/30047522500255258/

Important factors to consider

- Landscaping and building layout: Care should be taken to expose façades with opening windows to breezes and to avoid these being in the 'wind shadow' of other buildings and obstructions.
- Depth of the buildings: The depth of the building should not be more than 12-15m.
- Internal spatial layout: Air movement should be directed around people and the 'breeze path' between windows on opposite walls be made a direct as possible to ensure that air movement iseffective.

5.6 Night-time cooling

Night-time cooling uses the thermal mass of a building to absorb heat gains during the day, then cools the mass at night using external air and discharging accumulated heat to the outside so the temperature of the thermal mass is lowered ready for the next day.

Night-time cooling requires that the construction of the building includes significant thermal mass which is exposed both to the occupied spaces of the building and to ventilation paths (either directly, or by indirect convection). This can mean that buildings have exposed concrete floor slabs, exposed brick walls, no carpets, no suspended ceilings and so on. Thermal mass for night-time cooling is most efficient in horizontal surfaces, in particular floors, as cool ventilation air will tend to fall to the floor level.

Night-time cooling is particularly effective in climates with a large diurnal temperature range (an absolute minimum of 5°C), where external air temperatures are too high to provide adequate natural cooling during the day, but where night-time temperatures are low enough to 'pre-cool' the building ready for the next day.

The following factors should be considered in designing for night-time cooling:

- Openings: The design and location of openings should enable good airflow at night through the building. Airflow should be directed around thermal mass in order to remove heat at night.
- Security: Care should be taken to avoid compromising security.
- Thermal mass: The location of thermal mass within the building where it can act as heat sinkduring the day and be cooled by night-time ventilation.

5.7 Day lighting

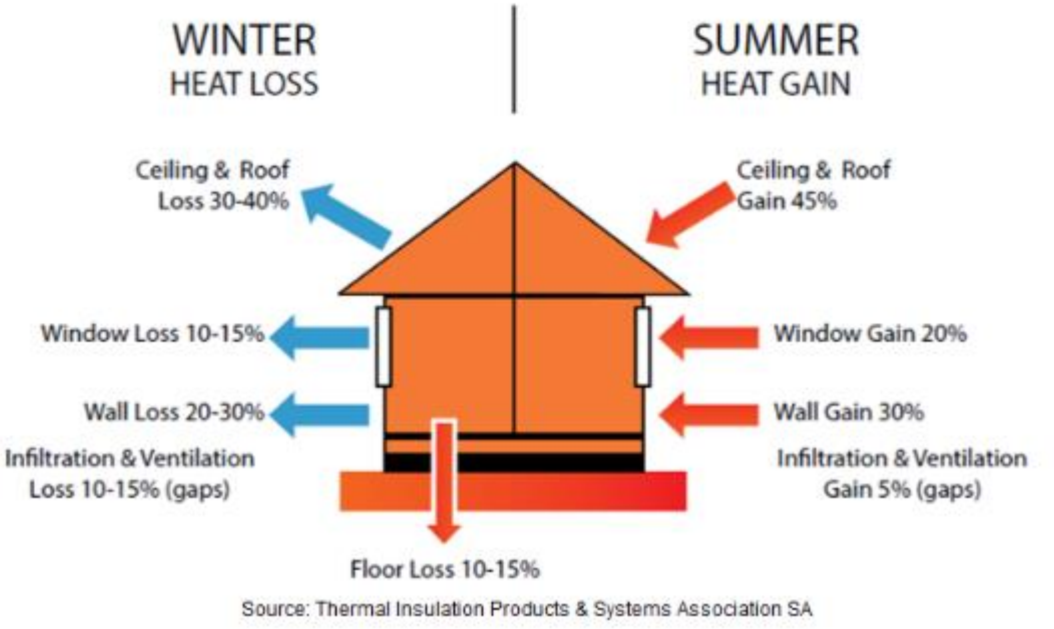
Good lighting design combines opportunities for using natural light with well-designed artificial lighting to provide energy-efficient lighting for spaces or specific tasks. Light bulb technology is also improving with lower-wattage fixtures now readily available. Daylight strategies should consider the following factors:

- Landscaping and building location to ensure good access to daylight.
- Depth of the buildings: The depth of the building should be limited to ensure that internal spaces that cannot be day lit are limited in area. A general rule of thumb is that daylight quality will be reasonable within the space 2h from a window, where h is the height of the head of the window from floor level
- Selection of glazing to allow good daylight penetration.
- Light shelves: The use of daylight shelves to enable daylight penetration deeper into the building.
- Internal colour: The choice of colour and finishes to improve internal reflectance of spaces.

5.8 Insulation

Insulation is installed to reduce heat loss or gain through the building envelope. Insulation acts as a barrier to heat flow, reducing heat loss in winter to keep the house/building warm or reducing heat gain in summer to keep the house/building cool. Inadequate insulation and air leakage are the main causes of heat loss in homes.

Figure 15: Approximate winter heat loss and summer heat gain



There are however some general guidelines:

- Insulation is a key part of any passive designed home, helping to keep heat inside the building in winter and outside the building in summer.
- The performance of any insulation product – how well it resists heat flow – is known as its R value. The higher the R value, the higher the level of insulation.
- Good orientation can significantly improve comfort and reduce heating and cooling needs. The best orientation for your building is the one that suits the climate zone.
- The 'total R value' adds together the R value of the various components of a roof, ceiling, wall or floor, including the insulation.
- The type and R value of insulation that is best suited to the building will depend on the climate and construction type.
- There are a wide range of insulation products. Bulk insulation uses air pockets within a thick material to slow the flow of heat. Reflective insulation reflects heat back to where it came from, and if double sided does not re-radiate heat on the opposite side. Composite insulation combines bulk insulation with a reflective surface.
- Thermal bridges are pathways for heat transfer through components of the floor, walls or roof. They need to be identified and insulated to prevent heat flow and condensation risk.

5.9 Glazing in façades

Glass in the construction and design of green buildings, can, in addition, enhance the aesthetics of a structure, improve its design, improve thermal performance and even create a comfortable environment for the occupants.

5.9.1 Eco-sense glass

Ecosense glass is designed prevent solar radiation from entering a space and delivers a cooling effect rather than a heating effect. It is an energy efficient solution that also allows natural light to pass through freely. It also absorbs and reflects a large amount of near range infrared heat. This enables it to keep the space within a structure and the occupants cool in every climate and weather.

5.9.2 Opal glass

This type is mainly designed to keep heat from entering the building. It is usually installed on building exteriors, facades and windows.

5.9.3 Sunshield glass

This type of glass drastically reduces glare and improves energy efficiency. It comes with a superior protective coating that keeps occupants safe from harmful UV rays.

5.9.4 Super-silver glass

Heat reflective glass which can be customized to provide thermal insulation, acoustic insulation and protection from UV radiation. Its glazing properties allow it to reflect light during the day, thereby enhancing the privacy of a space.

The following guidelines can be used to support energy efficiency:

- Optimal balance between daylight quality and heat gains and losses. Glass generally has a much lower R-value than solid walls. Therefore in highly glazed areas it may be difficult and expensive to control heat gains and losses. If areas are going to be highly glazed, high-performance glazing should be investigated in order minimise discomfort and energy consumption (see below).
- Where possible, glazing should be avoided on east, west façades and to minimize glazing in the south as there is no direct sunlight in winter and also to minimise direct sunlight in summer. Glazing should also be placed where it provides views and higher up in walls to support good day lighting.

5.10 Windows

Well-designed windows can improve the energy efficiency through enabling good daylight and natural ventilation. Characteristics of windows that can be used to support energy efficiency are outlined below:

- Where windows are being used as part of a cross ventilation strategy, the size and location of opening sections should be designed to ensure that breeze paths through the building are direct and are guided through areas, equipment and people that need ventilation and cooling.
- Naturally ventilated buildings should have an equivalent opening area (of windows or doors) of at least 5% of the floor area.

- Light coloured chamfered reveals help reduce contrast between windows and surrounding walls reducing glare and improving day lighting.
- Windows with opening sections at both high- and low-level benefit from being able to use the stack effect to create air movement and can be used to vent hot air out of the top of rooms and draw in cooler air in at low levels.
- Window opening controls should be designed to give occupants control over their local environment. This can be done by having regularly spaced windows and providing at least one opening section per 5 m of façade. Window controls should also cater for people with disabilities

5.11 Glass

Glazing simply means the windows in the building, including both openable and fixed windows, as well as doors with glass and skylights. It is typically used to refer to all aspects of an assembly including glass, films, frames and furnishings. Paying attention to all of these aspects will help you to achieve effective passive design.

- Glazing – the glass and frames in windows, external doors and skylights – has a significant effect on thermal performance. Up to 40% of a building's heating energy can be lost and up to 87% of its heat gained through windows.
- Improving the thermal performance of the glazing will increase the building's comfort and reduce energy consumption, therefore lowering costs and greenhouse gas emissions.
- The thermal performance of a window, door, or skylight depends on how well the glass and frame conduct heat (conduction or U value) and how well the glass and frame transmit heat from direct sunlight. Increasing U-values by using double-glazing, reduces heat losses and gains.

5.12 Doors

The function of doors is similar to that of windows in ventilation and cooling of buildings. Doors can let in hot or cold air into the building. Doors that are considered to have sustainable qualities must be especially good at creating a seal between the outside and inside, and a large part of energy conservation is about reducing heat (or cold) exchange with the outdoors. A good exterior door will fit tightly and use the best available weather-stripping technology. The most energy-efficient doors are made of fiberglass or wood-clad steel, or painted steel, filled with a core of polyurethane foam.

6. LIGHTING

6.1 Artificial lighting

In buildings, artificial lighting can account for up to 10% of a building's annual electricity use. If the current green lighting technology and designing techniques to minimize the need for artificial lighting, this can potentially decrease lighting energy use in buildings by 50-70%.

Green lighting design matches the amount of quality of light to the function of a space. Sections of lighting for different areas or different functions should be on separate controls, to allow users of a space to decide how much light is needed. Task lights should be installed where needed, and ambient light reduced elsewhere. Occupancy sensors that automatically turn lights on and off as needed can reduce energy use while having a minimal impact on building occupants. Opportunities for daylighting should be maximized, while controlling glare and unwanted heat gain.

The first stage of lighting design is to decide on an appropriate lighting level, measured in lux. As part of the building design process, lighting designers should develop lighting solutions that addresses:

- Daylighting—the design should supplement the available daylight.
- Task / Ambient systems - Required light levels for different areas are outlined in applicable standards (SANS 10400 for South Africa) and should be followed.
- Control of systems—with daylight, occupancy, schedule, time, and user preference.
- Efficient and effective luminaires—making the best use and distribution of the light source.
- Efficacious light sources—designer should choose the most efficacious (lumens of light per watt of power) that still accomplishes the design goal for that source and luminaire.
- Exterior Lighting—while enough light needs to be provided for night-time visibility, too much can cause glare, adaptation problems, and light trespass
- Energy efficiency: Energy efficient lighting systems should be selected. Good indicators of energy efficiency are luminous efficacy and energy requirements per square meter.
- Colour rendering: The extent to which colours are rendered effectively can be important, particularly in museum, art gallery and retail environments.
- Maintenance: The cost of replacing lamps can be considerable, particularly in difficult-to-access locations such as atria or auditorium roofs. The lifespan of lamps may therefore be an important factor

6.2 Lighting Technology

In terms of energy efficiency, lighting technology has been changing rapidly in recent years. The main ones being new high-intensity light emitting diodes (LEDs). A good indicator of energy efficiency in lamp selection is the luminous efficacy in lumens per Watt. Luminous efficacy is a measure of how well a light source produces visible light.

The different lamp lumen comparisons are given the table below:

Table 4: Lumen comparison – general purpose bulbs

General Purpose Bulbs				
Lumens	**Incandescent**	**High Intensity Discharge**	**Compact Fluorescent Lamp**	**Light Emitting Diode**
250 lm	25W	18W	6W	2W - 3W
560 lm	40W	29W	10W	3W - 6W
800 lm	60W	43W	13W	7W -10W
1100 lm	75W	53W	18W	10W - 15W
1600 lm	100W	72W	23W	15W - 20W
2600 lm	150W	100W	42W	20W - 30W
https://www.takethreelighting.com/lumen-watt-comparison.html				

Table 5: Lumen comparison – linear tubes

Linear Tubes: Lumen Comparison					
Initial Lumens	**Mean Lumens**	**Fluorescnt**	**Lumens**	**LED**	
1400 lm	1300 lm	17W T8	1200 lm	8W - 10W	
2500 lm	2000 lm	25W T8	1400 lm	11W - 13W	
3100 lm	2800 lm	32W T8	1900 lm	14W - 20W	
5000 lm	4800 lm	54W T5	3200 lm	25W - 30W	
https://www.takethreelighting.com/lumen-watt-comparison.html					

Table 6: Lumen comparison – high output

High Output: Lumen Comparison				
Initial Lumens	**Mean Lumens**	**Metal Halide**	**Lumens**	**LED**
3400 lm	2000 lm	50W	1000 lm	10W - 12W
5600 lm	3700 lm	70W	2000 lm	15W - 20W
8500 lm	4600 lm	400W	2500 lm	20W - 25W
10000 lm	6000 lm	125W	3200 lm	28W - 30W
11000 lm	8000 lm	150W	4600 lm	36W - 40 W
15000 lm	9000 lm	175W	5800 lm	45W - 60W
22000 lm	14000 lm	250W	7000 lm	54W - 70W
36 000 lm	22 000lm	400W	14000 lm	100W - 120W
https://www.takethreelighting.com/lumen-watt-comparison.html				

Specifications for lighting are given in the following publications from the South African Bureau of Standards:

- SANS 10114-1 Interior lighting, Part 1: Artificial lighting of interiors.
- SANS 10389-1 Exterior lighting, Part 1: Artificial lighting of exteriors.
- SANS 10098-1 Public lighting, Part 1: The lighting of public thoroughfares.

6.3 Energy consumption

Energy consumption in lighting should be evaluated against best practice benchmarks. A benchmark that can be used are the power density and maximum average annual energy consumption figures outlined below from SANS 204. Classification of occupancy of building are;

A1: Entertainment & Public Assembly

A2: Theatrical & Indoor Sport

A3: Places of Instruction

A4: Worship

F1: Large Shop

G1: Offices

H1: Hotel

Table 7: Maximum energy demand & energy usage per class of occupancy or building

Class of occupancy or building	Occupancy	Population	Recommended good practice maximum values	
			Power watts per m²	Energy kilowatts- hours per annum per m²
A1	Entertainment & Public assembly	Number seats or 1 person/m²	10	25
A2	Theatrical & indoor sport	Number seats or 1 person/m²	10	25
A3	Places of instruction	1 person / 5 m²	10	25
A4	Worship	Number seats or 1 person/m²	10	10
A5	Outdoor sport is viewed	Number seats or 1 person/m²	10	15
B1	High risk commercial	1 person / 15 m²	24	60
B2	Moderate risk commercial	1 person / 15 m²	20	50
B3	Low risk commercial	1 person / 15 m²	15	37.5
C1	Exhibition Halls	1 person / 10 m²	15	22.5
C2	Museums	1 person / 20 m²	5	12.5
D1	High riskindustrial	1 person / 15 m²	20	50
D2	Moderate risk industrial	1 person / 15 m²	20	50
D3	Low risk industrial	1 person / 15 m²	15	37.5
D4	Plant rooms		5	5
E1	Places of detention	2 person /bedroom	15	37.5
E2	Hospitals	1 person / 10 m²	10	87.6
E3	Other institutional residences	1 person / 10 m²	10	25
F1	Large shops	1 person / 10 m²	24	105.12
F2	Small shops	1 person / 10 m²	20	87.6
F3	Wholesaler’sstore	1 person / 20 m²	15	65.7
G1	Offices	1 person / 15 m²	17	42.5
H1	Hotels	2 person /bedroom	10	43.8
H2	Dormitories	1 person / 5 m²	5	12.5
H3	Domestic residences	2 person /bedroom	5	5
H4	Dwelling houses	4 person / house	5	5
J1	High risk storage	1 person / 50 m²	17	42.5
J2	Moderate riskstorage	1 person / 50 m²	15	37.5
J3	Low risk storage	1 person / 50 m²	7	17.5
J4	Parking areas	1 person / 50 m²	5	21.9

	covered			
Source: SANS 204:211. Energy Efficiency in Buildings (www.sabs.co.za)				

6.4 Lighting Controls

The purpose of lighting controls is used to give building occupants control of the lighting while providing appropriate lighting levels, minimizing glare, balancing surface brightness, and enhancing the surrounding architecture.

When this is used properly, energy will be saved and the life of lamps and ballasts can be extended. Lighting controls will help reduce energy by:

- Reducing the amount of energy used during the peak demand period by automatically dimming lights or turning them off when they are not needed
- Reducing the number of hours per year that the lights are on
- Reducing internal heat gains by cutting down lighting use, which allows for reduced HVAC system size and a reduction in the building's cooling needs
- Allowing occupants to use controls to lower light levels and save energy

The table below provides control ideas for several different room types and usage patterns.

Some additional links to help on manufacturers' web sites are provided below the table.

Table 8: Types of recommended lighting controls

Space Type	**Typical Use Pattern**	**If …**	**Then …**
Cafeterias or Lunchrooms	Occasionally occupied	Daylighted	Consider daylight-driven dimming or on/off control
		Occupied occasionally	Consider ceiling-mounted occupancy sensor(s). Make sure minor motion will be detected in all desired locations.
Classroom	Usually occupied	Multiple tasks like overhead projectors, chalkboard, student note taking and reading, class demonstrations	Consider manual dimming
	Occasionally occupied	Occupied by different groups of students and teachers daily	Consider ceiling- or wall-mounted occupancy sensor(s) and manual dimming. Make sure that minor motion will be detected.
		Lights left on after hours	Consider centralized controls and/or occupancy sensors.
Computer Room	Usually unoccupied	Lights are left on all the time	Consider occupancy sensors with manual dimming. Be sure that minor motion will be detected and that equipment vibration will not falsely trigger the sensor.
Conference Room	Occasionally occupied	Multi-tasks from videoconferencing to presentations	Consider manual dimming (possibly pre-set scene control)
		Small conference room	Consider a wall box occupancy sensor

		Large conference room	Consider ceiling- or wall-mounted occupancy sensor(s). Be sure that minor motion will be detected in all desired locations.
Gymnasium or Fitness	Usually occupied	Requires varied lighting levels for activities	Consider manual dimming and occupancy sensors. Be sure that the HVAC system will not falsely trigger the sensor.
	Occasionally occupied	Requires varied lighting levels for activities	Consider ceiling- and wall-mounted passive infrared occupancy sensors. Be sure that the coverage areas of the sensors are sufficiently overlapped to keep the lights on when the room is occupied.
Hallways	Any	Occasionally or usually occupied	Consider occupancy sensors with elongated throw. Be sure that coverage does not extend beyond the desired area.
		Daylighted	Consider daylight on/off control.
Health Care—Examination Rooms	Occasionally occupied	Different lighting needs for examination	Consider manual dimming.
		Small areas	Consider a wall box occupancy sensor.
Health Care—Hallways	Usually occupied	Daylighted	Consider automatic daylight-driven dimming.
		Requires lower lighting level at night	Consider centralized controls to lower lighting levels at night.
Health Care—Patient Rooms	Usually occupied	Different lighting needs for watching television, reading, sleeping, and examination	Consider manual dimming. Occupancy sensors may not be appropriate.
Hotel Rooms	Occasionally occupied	Used primarily in the late afternoon through evening for sleeping and relaxing	Consider manual dimming
Laboratories	Usually occupied	Daylighted	Consider automatic daylight-driven dimming in combination with occupancy sensors.
Laundry Rooms	Occasionally occupied	Requires high light levels, yet lights are usually left on	Consider occupancy sensors.
Libraries—Reading Areas	Usually occupied	Daylighted	Consider automatic daylight-driven dimming. Occupancy sensors may be appropriate.
		Lights left on after hours	Consider centralized controls.
Libraries—Stack Areas	Occasionally occupied	Stacks are usually unoccupied	Consider ceiling-mounted sensor(s).
Lobby or Atrium	Usually occupied but no one "owns" the space	Daylighted and lights should always appear on	Consider automatic daylight-driven dimming.
		It isn't a problem if lights go completely off in high daylight	Consider automatic daylight-driven dimming or on/off control.
		Lights are left on all night long, even when no one is in the area for long periods	Consider occupancy sensors. Be sure that minor motion will be detected in all desired areas.
Office, Open	Usually occupied	Daylighted	Consider automatic daylight-driven dimming.
		Varied tasks from computer usage to reading	Consider manual dimming.
		Lights left on after hours	Consider centralized controls and/or occupancy sensors.
Office, Private	Primarily one person, coming and going	Daylighted	Consider manual dimming, automatic daylight-driven dimming, or automatic on/off.
		Occupants are likely to leave lights on and occupants would be in	Consider a wall box occupancy sensor. Add dimming capabilities if appropriate.

		direct view of a wall box sensor	
		Occupants are likely to leave lights on and partitions or objects could hide an occupant from the sensor	Consider a ceiling- or wall-mounted occupancy sensor. Add dimming capabilities if appropriate.
Photocopying, Sorting, Assembling	Occasionally occupied	Lights are left on when they are not needed	Consider an occupancy sensor. Be sure that machine vibration will not falsely trigger the sensor.
Restaurant	Usually occupied	Daylighted	Consider automatic daylight-driven dimming.
		Requires different lighting levels throughout the day	Consider manual dimming (possibly preset scene dimming).
		Requires different lighting levels for cleaning	Consider centralized control.
Restroom	Any	Has stalls	Consider a ceiling-mounted ultrasonic occupancy sensor for full coverage.
		Single toilet (no partitions)	Consider a wall switch occupancy sensor.
Retail Store	Usually occupied	Daylighted	Consider automatic daylight-driven dimming
		Different lighting needs for retail sales, stocking, cleaning	Consider centralized controls or pre-set scene dimming control.
Warehouse	Aisles are usually unoccupied	Daylighted	Consider daylight-driven dimming or daylight on/off control.
		Lights in an aisle can be turned off when the aisle is unoccupied	Consider ceiling-mounted occupancy sensors with elongated throw. Select a sensor that will not detect motion in neighbouring aisles, even when shelves are lightly loaded.
Source: https://www.wbdg.org/resources/electric-lighting-controls			

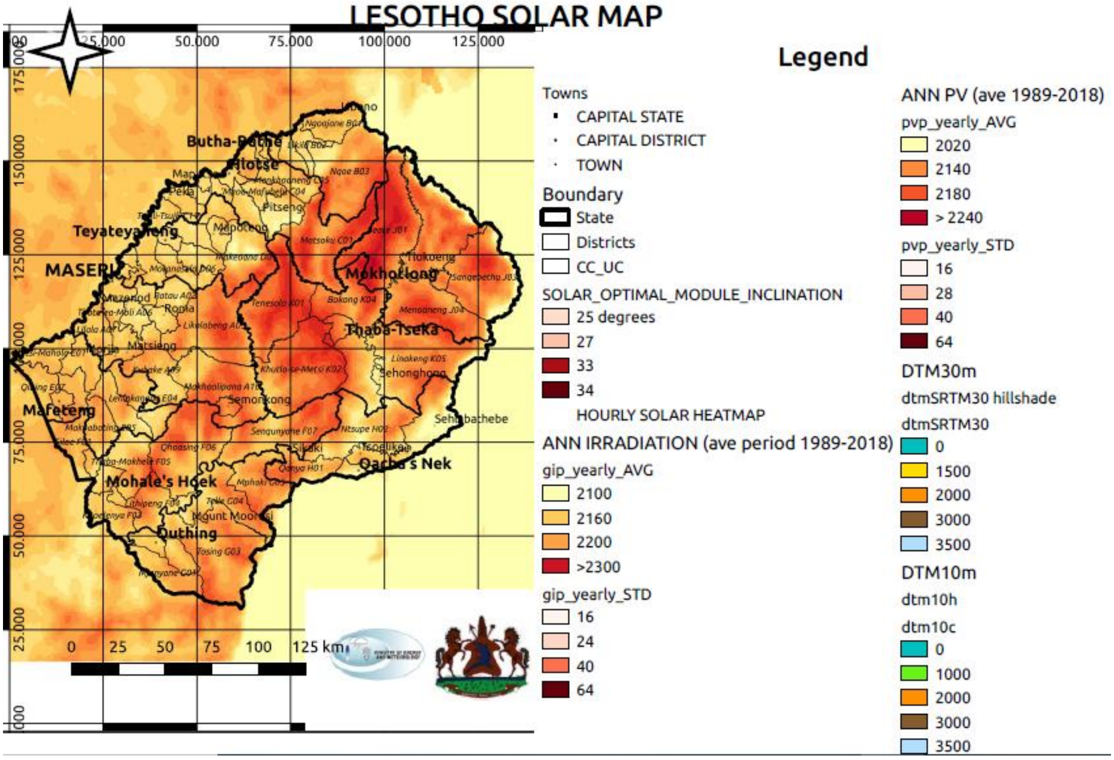
6.5 Renewable Energy (Solar PV & Thermal)

Renewable energy is energy that has been derived from earth's natural resources that are not finite or exhaustible, such as wind and sunlight. Renewable energy is an alternative to the traditional energy that relies on fossil fuels. It is less harmful to the environment.

Both existing and new developments should make use of renewable energy to reduce reliance on fossil-based fuels and related carbon emissions and attendant energy cost reduction. The most applicable include solar photovoltaic systems and solar thermal systems (water heating systems).

The manual recommends a minimum of 10% of the annual energy consumption of a building should be generated from renewable solar energy sources.

Table 9: Lesotho Solar Source Map



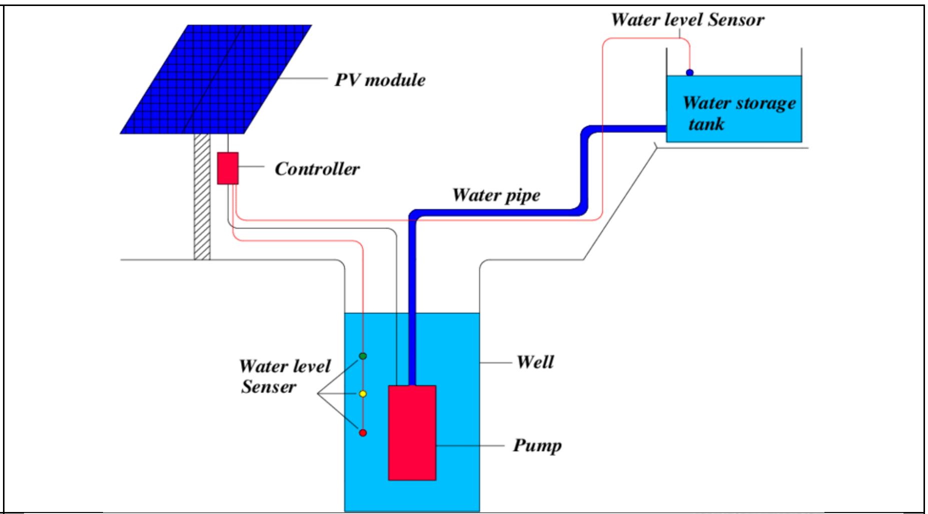
Source: Lesotho Department of Energy

6.5.1 Photovoltaic (PV) Systems

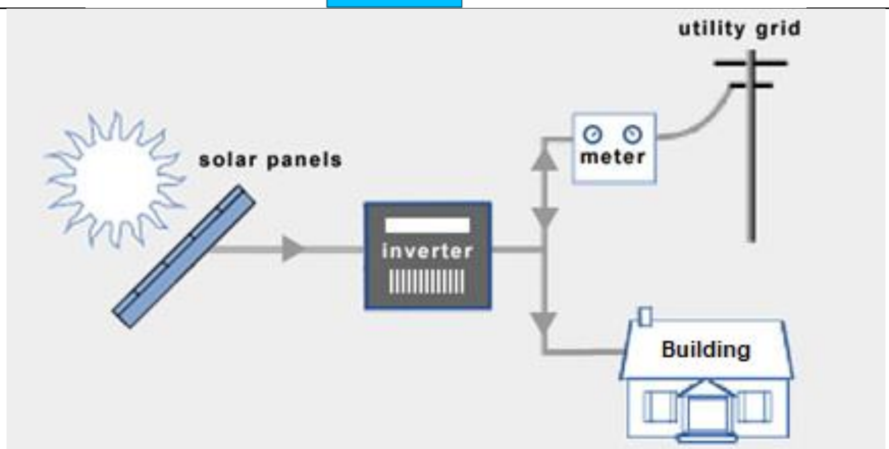
The cost of installing and maintaining Solar PV Systems have been steadily decreasing over the years. The simple payback period for a grid-tied system ranges from to 4 to 5 years. Storage batteries are still expensive and still push the prices 3 to 5 times that of a grid-tied system, The installation cost of a Solar PV System varies depending on the type of installation required by the property owner. Simple systems with no batteries for borehole pump, to hybrid systems with batteries and or connected to standby generators.

Figure 16: Typical General Configuration – Solar PV Systems

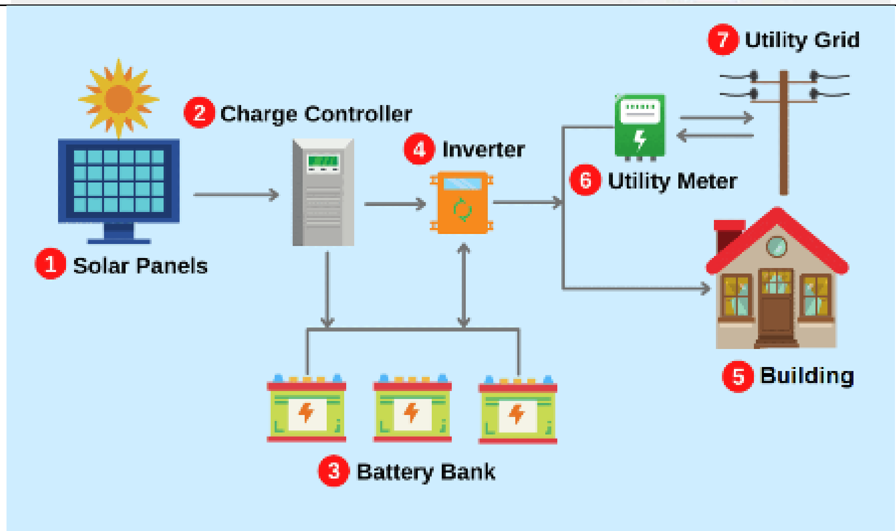
Solar-powered borehole pump



Grid-tied Solar PV System



Grid-tied Solar PV System with Battery Storage



6.5.2 Solar Thermal (Solar Water Heating)

Solar water heating (SWH) is heating water by sunlight, using a solar thermal collector. A variety of configurations are available at varying costs to provide solutions in different climatic zones.

The principle of operation is that a sun-facing collector heats a working fluid that passes into a storage system for later use. Two (2) types of SWH available, active (pumped) and passive (convection-driven). They use water only, or both water and a working fluid. They are heated directly or via light-concentrating mirrors. They operate independently or as hybrids with electric or gas heaters.

6.5.2.1 Thermosyphon Systems

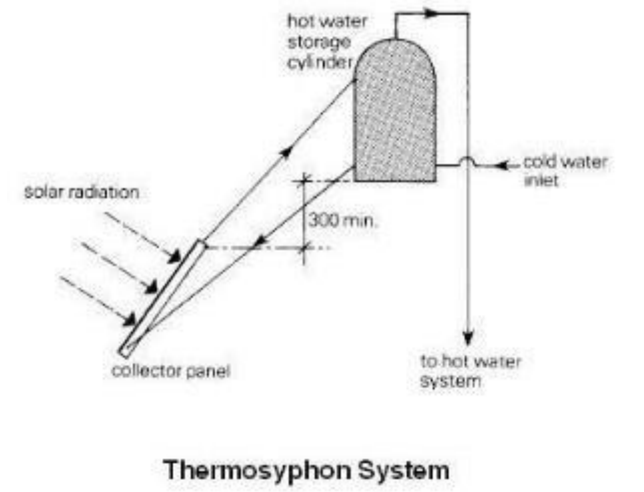
Natural convection drives the process, with the water heated within the collector naturally rising up to the tank and forcing the colder water down into the collector below.

Figure 17: Solar Thermosyphon System

Water in the solar collector is heated by the sun and rise to the top of the collector.

Due to the closed loop piping of the solar collector and the water heater (geyser), the warm water will rise to the geyser and cold water from the geyser will sink towards the bottom of the solar collector.

This means water is starting to circulate (siphon) through the solar collector and geyser as long as the sun is heating the water in the collector.

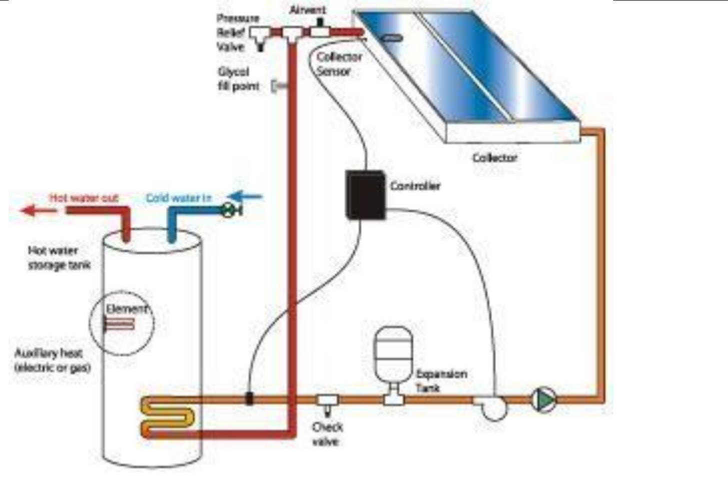
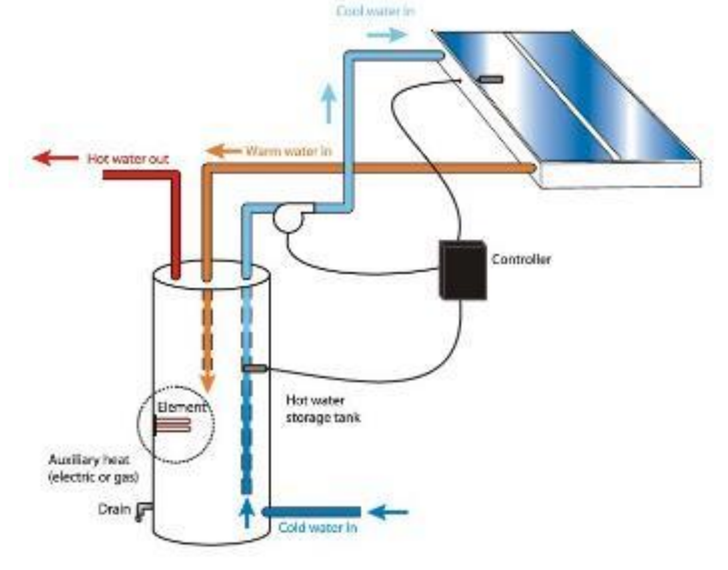


Source: https://www.helderbergsolarenergy.com/

6.5.2.2 Closed Loop Systems

A closed loop or sometimes known as an “active” solar system uses a mixture of glycol and water and is pressurized within the system. This requires a pump station to fill the system initially, however, all our solar water heating kits come with the fill pump. The system is pressurized to between 1.4 – 2.1bar gauge pressure. In a closed loop system, an expansion tank with a rubber membrane is present and absorbs the expanding and contracting of the heating system as it heats up and cools.

Figure 18: Schematics of Solar water systems

<table>
<tr><td>Closed hot water system</td><td>
</td></tr>
<tr><td>Active Open Loop System</td><td>
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6.5.3 Financing of Solar Thermal & Solar PV Systems

Sustainable Energy Fund for Africa (SEFA) is a multi-donor Special Fund managed by the African Development Bank.

6.5.4 Specifications & Minimum Standards

- Electricity and Water Authority (Electricity Supply) Regulations_2019
- South African National Standards (SANS) 10400-XA

7. MECHANICAL VENTILATION AND AIR CONDITIONING

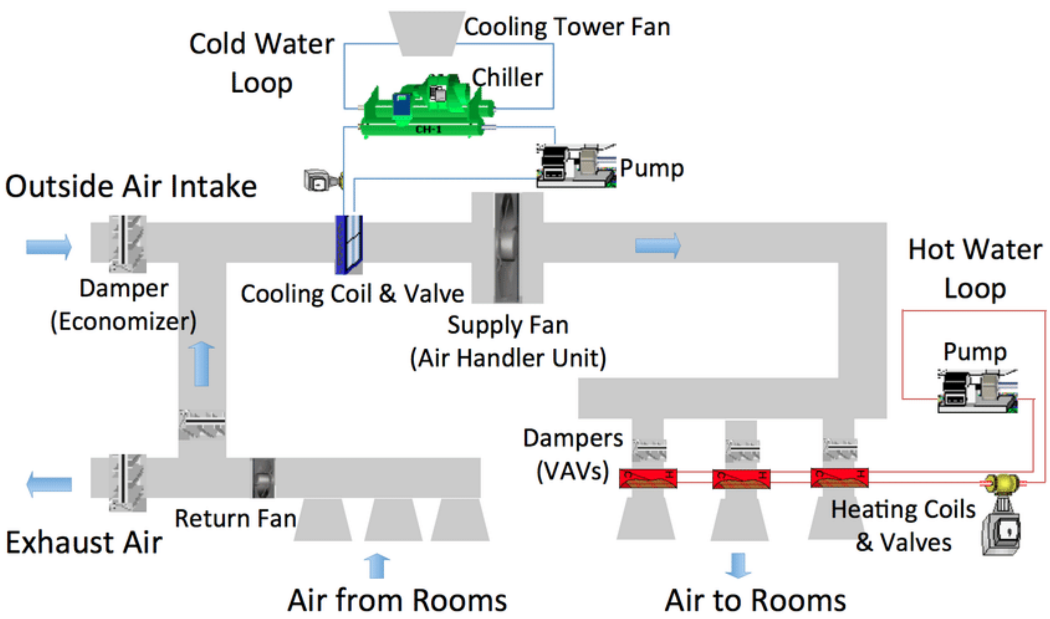
7.1 General

Ventilation is the process of replacing indoor air with fresh air from outside the building. Generally, there are two ways of ventilating a building; (i) by air leakage through cracks and openings in the building envelope and (ii) purposely provided ventilation in the form of natural, mechanical, or a combination of the two. In mechanical ventilation, the airflow is distributed by means of fans and ductwork arrangement throughout the building and then distributed in the room via air terminal devices or diffusers.

Types of ventilation

- Mechanical (or forced) ventilation is driven by fans or other mechanical plant.
- Natural ventilation is driven by pressure differences between one part of a building and another, or pressure differences between the inside and outside
- Natural ventilation is generally preferable to mechanical ventilation as it will typically have lower capital, operational and maintenance costs.

Figure 19: A typical HVAC system for a commercial building.



https://www.researchgate.net/

7.2 Energy Efficient Heating, Ventilation & Air Conditioning Systems

Ventilation systems primarily control the temperature of air inside the designated space along with control of humidity, filtration of air and containment of air borne particles, supply of outside fresh air for control of oxygen and carbon dioxide levels in the air-conditioned space, and finally control of the movement of air or draught. These systems from use considerable amount of energy.

The most effective way to reduce ventilation and air conditioning system's energy consumption is to reduce the heat load and use of natural ventilation. This is achieved via energy efficient HVAC design.

This is incorporated at the design stage of the building.

- Reducing the need for heating and cooling with adequate insulation and airtight construction.
- Purchasing air conditioners, space heaters and air handlers with a high nameplate efficiency.
- Making sure the thermostat is set correctly. When the temperature is set too low or too high, even the most efficient HVAC system will waste energy.

7.2.1 Ventilation and airtightness

Airtightness is about limiting the unintentional introduction of outdoor air into a building, or limiting the loss of air to the outside. The greater the airtightness, the less unintended air movement occurs. An airtight building is more energy-efficient than a leaky one, but good ventilation is essential to maintaining a healthy, comfortable indoor environment.

7.2.2 Zoning

Zoning a building into different areas depending on ventilation and heating and cooling requirements can enable mechanical systems to be used more efficiently. Thus an area with high ventilation requirements and heat gains such as a kitchen could be zoned and dealt with separately to other areas such as passageways, or storage where ventilation requirements are lower. Zoning also allows heating, cooling and ventilation to different areas of the building to be reduced to match requirements more closely.

Design teams should work closely with building developers and occupants and in order understand how the building will function and relate to the external environment in order to develop zoning and control systems that support energy efficiency

7.2.3 Split Systems

Split system air conditioners have indoor, outdoor units and controls. The latest energy efficient technologies such as inverter technology AC systems should be installed. This should be followed by required maintenance of the units.

8. GREEN BUILDING CERTIFICATION

8.1 Introduction

Green building certification systems are a set of rating systems and tools that are used to assess a building or a construction project's performance from a sustainability and environmental perspective. Such ratings aim to improve the overall quality of buildings and infrastructures, integrate a life cycle approach in its design and construction, and promote the fulfilment of the United Nations Sustainable Development Goals by the construction industry. Buildings that have been assessed and are deemed to meet a certain level of performance and quality, receive a certificate proving this achievement.

This Green Building Rating System applies to commercial buildings and not residential houses. However, the Government of Lesotho would require such ratings to high-rise residential buildings with a minimum floor space of $2000m^2$.

Two examples are given, the United Kingdom Building Research Establishment Environmental Assessment Method (BREEAM) and the South African Green Buildings Certification. These are sustainability assessment methods for buildings.

8.2 Building Research Establishment Environmental Assessment Method (UK)

BREEAM was established in 1990 and it is the world's longest established method of assessing, rating, and certifying the sustainability of buildings. It is an assessment undertaken by independent licensed assessors using scientifically based sustainability metrics and indices which cover a range of environmental issues. Its categories evaluate energy and water use, health and wellbeing, pollution, transport, materials, waste, ecology and management processes. Buildings are rated and certified on a scale of 'Pass', 'Good', 'Very Good', 'Excellent' and 'Outstanding'.

It works to raise awareness amongst owners, occupiers and designers of the benefits of taking a sustainable approach, providing a framework to help them to successfully adopt sustainable solutions in a cost-effective manner, and provides market recognition of their achievements. It aims to reduce the negative effects of construction and development on the environment.

8.3 The Green Building Council of South Africa

The Green Building Council SA (GBCSA) was formed in 2007 to lead the greening of South Africa's commercial property sector. They provide the tools, training, knowledge and networks to promote green building practices across the country and build a national movement that will change the way the world is built. GBCSA has developed the Green Star SA rating system and is the official certification body for Green Star SA projects.

The Green Star South Africa rating tool is an objective measurement for green buildings with a focus on energy. Building owners have to submit the relevant building data to the Green Building Council South Africa (GBCSA). Afterwards, an independent assessor evaluates the building and its green measures and rates it. The building owner then receives a certification with a 4-Star, 5-Star or 6-Star rating. 4 Star means "Best practice", 5 Star stands for "South African Excellence" and 6 Star means "World Leadership".

8.4 Energy Performance Certificates

An Energy Performance Certificate, similar to those displayed on household appliances, must be issued by an accredited body. An example is the South African SANS 1544:2014 Energy Performance Certificates for Buildings. This certificate must rank the energy rating (ER) of a building on a performance scale.

SANS 1544:2014 specifies the requirements for producing energy performance certificates for buildings. The standards cover

- The building is larger than 2000 square meters (if privately owned) or 1000 square meters (if owned by an organ of state).
- The building has not undergone major renovations in the last 2 years.
- The building's predominant occupancy class is one of the 4 listed below
    a) Office space (offices, banks, consulting rooms and similar usage)
    b) Entertainment and public assembly (where people gather to eat, drink, or participate in other recreation)
    c) Places of instruction (where school children, students, or other people assemble for the purpose of tuition or learning)
    d) Theatrical and indoor sports (where people gather to view theatrical, operatic, orchestral, choral, cinematographical or indoor sports performance)

8.5 Third-Party Product Certification

Third-party certification is a way to ensure that a product and company's claim to being green has integrity. A third-party certifier will ensure that the product's "green" claims are true. Third-party certifiers follow established and recognized guidelines to ensure their objectivity in granting certification. This means that the certifying body must be financially independent of the product and company that they are certifying, without ownership, funding, or consulting ties. Third-party certifiers must be: Independent. The first principle of certification is that it should be granted by an independent, third-party with no vested interest in the product that is being certified. Verifiable. The second principle of certification is that all claims must be scientifically verifiable. If a claim cannot be verified using scientific methods of evaluation, then it should not be certified. Complete. The third principle of certification is that it must be a complete process, with appropriate checks and balances to ensure the accuracy of final results.

9. COMMON BUILDING MATERIALS

Different materials are used for building depending on their physical, chemical and thermal properties, aesthetics and cost. The most common ones being concrete, steel, stones and bricks for commercial and urban residential buildings.

9.1 Concrete

Concrete is made from fine and coarse aggregate mixed with cement and water. Concrete takes seven days to cure and an average of 28 days to attain maximum strength. Because of its cost and versatility, concrete is a common material in construction and is used for foundations, residential and commercial building construction.

9.2 Steel

Steel is a composite material made from alloys of iron and carbon and has high strength to weight ratio. It is lightweight, easy to work with, and cheaper to transport than other building materials. Steel does not easily deform, and it retains its structural properties even when it is bent. If should be correctly installed to prevent corrosion and it can also break when exposed to high temperatures. It is commonly used for structural sections, roofing and internal structures .

9.3 Wood

It is naturally available and cost-efficient, strong and durable, and flexible. It can be bent, moulded, or cured into desirable shapes. Other than its durability, wood is an environmentally sustainable material. Wood works well with other materials such as steel, marble, and aluminium. Compared to other construction materials, wood is relatively light and easy to standardize in size. It has high tensile strength and is good in soundproofing and insulation. It is used for constructing walls, floors, and ceilings, frames of structures in buildings, thermal and acoustic insulation.

9.4 Stone

Stone is the longest-lasting building material. We commonly use stone in walls and floorings, and the texture makes it versatile. Stone comes with smooth finish textures to rough ones and also comes in many different colours. Examples of stones used in construction are sandstone, granite, and marble. Ordinary stone is cheap, but the prices go up for unique finishes.

9.5 Bricks / Masonry

Masonry uses bricks which are rectangular blocks, and they are later bound with mortar. Bricks were traditionally made from heated and dry clay. They have a high compression resistance, but they can break easily. The most vital bricks in existence now are concrete blocks which are reinforced using steel. Masonry is fire-resistant and durable.

9.6 The importance of selecting the correct materials

Material selection is fundamental in any building project or renovation and suitability of materials is better than cost consideration. Some of the considerations in selecting the correct materials.

9.6.1 Durability

Durability is the ability to last a long time without significant deterioration. A durable material helps the environment by conserving resources and reducing wastes and the environmental impacts of repair and replacement. Durable construction materials won't need frequent repairs and replacements; therefore, one can distribute the raw materials, and environmental and energy impacts over time.

9.6.2 Cost

The cost of materials is a vital discussion point between engineers, the client, and the architect. However, looking for the most affordable product without considering its lifespan and utility is not always desirable. This is an area where government interventions might be warranted if market forces alone are not working

9.6.3 Environmental impact of a material

The choice of construction materials is primarily made on cost, structural, and thermal properties. However, building materials have environmental implications, such as pollution and energy consequences in the manufacturing processes.

Poor quality construction materials also increase waste issues throughout the stages of construction. Construction materials affect the lifecycle and recycling options during a project's expected life.

9.7 Properties of Construction Materials

A building is a structure built with materials and including with foundation, plinth, walls, floors, roofs, chimneys, plumbing, and building services, fixed platforms, veranda, balcony, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures.

Building material is also defined as any material that is used for a construction purpose. There are many natural materials, such as clay, sand, wood, grass and rocks which are in construction. Made-made or synthetic materials such as cement, bricks, and concrete blocks. Construction materials vary in their physical, mechanical, and chemical properties. It is important therefore to understand the properties of building materials as this helps to select the suitable materials at the lowest possible cost.

9.8 Common Characteristics

For a material to be considered as building material, it should have required engineering properties suitable for construction works. These properties of building materials are responsible for its quality and capacity and helps to decide applications of these material. Such properties of building materials are categorized as follows.

The main categories of building materials include physical properties, mechanical properties, chemical properties, electrical properties, magnetic properties and thermal properties. The common ones highlighted in this section are physical and thermal properties.

9.8.1 Bulk density

Bulk density is the ratio of mass to the volume of the material in its natural state that is including voids and pores. It is expressed in kg/m^3. Bulk density influences the mechanical properties of materials like strength, heat and conductivity etc. bulk density values of some of the engineering materials are given below.

9.8.2 Thermal Conductivity

The amount of heat transferred through unit area of specimen with unit thickness in unit time is termed as thermal conductivity. It is measured in kelvins. It depends on material structure, porosity, density and moisture content. High porous materials, moist materials have more thermal conductivity.

9.8.3 Specific Heat Capacity

Specific heat is the quantity of heat required to heat 1 N of material by 1^oC. Specific heat is useful when we use the material in high temperature areas. Specific heat values of some engineering materials are given below.

Table 10: Common Properties

Material	Specific heat capacity (J/(kg K))	Thermal conductivity (W/m·K)	Density (kg/m^3)
Water	4,200	0.600	1,000
Stone	1,000	1.800	2,300
Brick	800	0.730	1,700
Concrete	1,000	1.130	2,000
Unfired clay bricks	1,000	0.210	700
Dense concrete block	1,000	1.630	2,300
Gypsum plaster	1,000	0.500	1,300
Aircrete block	1,000	0.150	600
Steel	480	45.00	7,800
Timber	1,200	0.140	650
Mineral fibre insulation	1,000	0.035	25
Carpet	-	0.050	-

9.9 Insulation Properties

Walls			
Material	Description (Inch)	Description (mm)	"U" Factor
Flat Metal	0" Fiberglass Insulation	0 mm Fiberglass Insulation	1.2
	1" Fiberglass Insulation	25.4 mm Fiberglass Insulation	0.22
	2" Fiberglass Insulation	50.8 mm Fiberglass Insulation	0.12
	3" Fiberglass Insulation	76.2 mm Fiberglass Insulation	0.09
	4" Fiberglass Insulation	101.6 mm Fiberglass Insulation	0.07
	6" Fiberglass Insulation	152.4 mm Fiberglass Insulation	0.05
	8" Fiberglass Insulation	203.2 mm Fiberglass Insulation	0.041
	12" Fiberglass Insulation	304.8 mm Fiberglass Insulation	0.027
Masonry	8" Brick	203.2mm Brick	0.41
	12" Brick	304.8mm Brick	0.31
	16" Brick	406.4mm Brick	0.25
	8" Conic Block, Solid	203.2mm Conic Block, Solid	0.39
	12" Conic Block, Solid	304.8mm Conic Block, Solid	0.36
	4" Conic Block, Hollow	101.6mm Conic Block, Hollow	0.51
	8" Conic Block, Hollow	203.8mm Conic Block, Hollow	0.39
	12" Conic Block, Hollow	304.8mm Conic Block, Hollow	0.37
Poured Concrete	2" Thick	50.8mm Thick	0.99
(140 lb. / ft3)	4" Thick	101.6mm Thick	0.86
(2242.58kg/m3)	6" Thick	152.4mm Thick	0.75
	8" Thick	203.2mm Thick	0.67
	10" Thick	254mm Thick	0.61
	12" Thick	304.8 mm Thick	0..55
Poured Concrete	2" Thick	50.8mm Thick	0.62
(80 lb. / ft.3)	4" Thick	101.6mm Thick	0.42
(1281.48kg/m3)	6" Thick	152.4mm Thick	0.31
	8" Thick	203.2mm Thick	0.25
	10" Thick	254mm Thick	0.21
	12" Thick	304.8 mm Thick	0.18

Doors		
Material	Description	"U" Factor
Steel	No Fiberglas Insulation	1.2
	Insulated	0.65
Wood	1"(25.4mm) Thick	0.64

Roofs (1 inch = 25.4mm)

Material	Description	"U" Factor
Flat Metal – Roof	0" Fiberglass Insulation	0.9
	1" Fiberglass Insulation	0.26
	2" Fiberglass Insulation	0.16
	3" Fiberglass Insulation	0.11
	4" Fiberglass Insulation	0.071
	6" Fiberglass Insulation	0.05
	8" Fiberglass Insulation	0.039
	12" Fiberglass Insulation	0.027
Wood – Roof	0" Fiberglass Insulation	0.48
	1" Fiberglass Insulation	0.21
	2" Fiberglass Insulation	0.12
	3" Fiberglass Insulation	0.1
	4" Fiberglass Insulation	0.075
	6" Fiberglass Insulation	0.052
	8" Fiberglass Insulation	0.04
	12" Fiberglass Insulation	0.027
Concrete Deck – Roof	2" Thick	0.3
	3" Thick	0.23
	4" Thick	0.18
Sky Lights	Single Wall	1.15
	Double Wall	0.7

Windows		
Material	Description	"U" Factor
Glass	Single Pane	1.22
	Double Pane	0.7
Fiberglass Panels		1.09

9.10 Thermal Insulation of Houses

9.11 External walls

Any external wall forming the enclosure of a dwelling house or dwelling unit to be erected in Climatic Zone 1, 2 & 3, excluding a door, window or glazed side shall comply with minimum requirements for resistive and capacitive insulation and surface absorbance below.

Table 11: Insulation requirements for external walls

Climatic Zone	Resistive Insulation U-value ($W/m^{2o}C$)	Capacitive Insulation A-value ($W/m^{2o}C$)	Surface Absorbance Factor
1	2.5	5	0.5
2	2.0	5	0.6
3	1.8	6	0.6

9.12 Roofs

The roof construction of all dwelling houses or dwelling units to be erected in Climatic Zones 1, 2 & 3 shall include an insulated ceiling and the thermal performance of the combined construction roof and ceiling shall comply with the minimum requirements for resistive, capacitive and reflective insulation contained in the table below

Table 12: Insulation requirements roofs

Climatic Zone	Resistive Insulation U-value ($W/m^{2o}C$)	Capacitive Insulation A-value ($W/m^{2o}C$)	Surface Absorbance Factor
1	0.7	-	-
2	0.7	3.3	-
3	0.7	3.3	3.0

9.13 Floors

The floor of a dwelling house or dwelling unit to be erected in Climatic Zones 1, 2 or 3 shall comply with the minimum requirements for resistive, capacitive and reflective insulation contain in the table below

Table 13: Insulation requirements for floors

Climatic Zone	Resistive Insulation U-value ($W/m^{2o}C$)	Capacitive Insulation A-value ($W/m^{2o}C$)
1	0.8	-
2	0.8	3.3
3	0.8	3.3

9.14 Windows

To maximise on absorption of solar energy through windows in direct gain in buildings for human habitation, the following rules shall be observed

- Glazed areas shall be maximised to the north, kept moderate on the east, small on the west and minimised on the south facing walls of the building.
- At least half of the total windows area of the building shall face north
- The areas of the north-facing window shall be approximately one fourth of the room's floor area.

9.14.1 Curtains

Thermal insulated curtains can be used to optimise the levels of heat in any room. Due to the specific insulated fabric, these curtains help less heat to escape through windows thereby increasing energy efficiency.

9.14.2 Double glazing

The gap is sealed, and acts as a break between the inside and outside pieces of glass. The air gap is filled with gas which increases the insulation between the glass pieces. Double glazed windows are highly efficient, reducing your heat loss or gain by up to 30% when compared to single-glazed windows.

9.14.3 Thermal film insulation

The thermal insulation film works on the principle of double glazing. It adds an extra film to the glazing to improve insulation and prevent heat loss and heat exchange. Once installed, it reduces heat loss by 33% in winter. The film is completely transparent and does not block light. It is suitable for all types of windows and glazing. It is easy to fit, adjusts to the size of your windows, and is installed on the inside.

Figure 20: Thermal film insulation

Values	SINGLE CLEAR GLASS 4 MM		DOUBLE GLAZING 4 - 15 ARGON - 4 MM	
Ug without film	5,8		2,6	
Ug with Solar 50 C	4,2	Energy savings 27 %	2,2	Energy savings 15 %
Ug with Solar 80 C	3,8	Energy savings 34 %	2,1	Energy savings 19 %
Solar factor without film	0,87		0,80	
Solar factor with Solar 50 C	0,40	Energy rejected 60 %	0,50	Energy rejected 50 %
Solar factor with Solar 80 C	0,18	Energy rejected 82 %	0,34	Energy rejected 66 %

https://www.solarscreen.eu/en/blog/film-window-insulation

Table 14: Summer conditions – heat flow reductions

Thickness	U-Value Transmittance (U) – W/m².EC	R- Value Thermal Resistance (R) – m².EC/W	Reduction in heat flow %
No insulation	2.35	-	-
75mm	0.43	1.88	82
100mm	0.34	2.5	85
115mm	0.3	2.88	87
130mm	0.27	3.25	88
135mm	0.26	3.38	89

Source: https://thermguard.co.za/technical-info/

Table 15: Summer conditions – heat flow reductions

Thickness	U-Value Transmittance (U) – W/m².EC	R- Value Thermal Resistance (R) – m².EC/W	Reduction in heat flow %
No insulation	3.09	-	-
75mm	0.45	1.88	85
100mm	0.35	2.5	89
115mm	0.31	2.88	90

130mm	0.28	3.25	91
135mm	0.27	3.38	91

Source: https://thermguard.co.za/technical-info/

These construction materials are available from South Africa. However, looking at the scale of interventions required in the housing sector, including the retrofit and upgrading existing houses and other commercial buildings, it is worthwhile for the Government of Lesotho to consider local production of these materials.

9.14.4 Climatic Zone I: Minimum Permitted U-Values

Table 16: Lowlands (up to 1800m above sea level)

No	Building component	R-Value (m^2.K/W)	U-Value (W/m^2.K)
1.)	External north facing wall	0.4	2.50
	External east/west facing wall	0.5	2.00
	External south facing wall	0.5	2.00
	Wall separating two distinct units	0.4	2.50
	Floor in contact to ground	0.5	2.00
	Floor over basement	1.33	2.00
	Floor separate two distinct units	1.33	0.75
2.)	Solar floor	1.33	0.75
	Roof	1.43	0.70
3.)	Windows of main rooms	0.17	6.00
	Windows of main rooms	0.80	1.25

1.) The degree of absorption ≥ 60%, time lag = 6.0h, mass density ≥ 1800kg/m^3
2.) Degree of absorption ≥ 60%, active mass density ≥ 2000kg/m3, thickness ≥ 60mm
3.) With removable thermal insulating shutters or curtains

9.14.5 Climatic Zone II: Minimum Permitted U-Values

Table 17: Foothills (from1800m to 2200m above sea level)

No	Building component	R-Value (m^2.K/W)	U-Value (W/m^2.K)
1.)	External north facing wall	0.4	2.50
	External east/west facing wall	0.5	2.00
	External south facing wall	0.5	2.00
	Wall separating two distinct units	0.4	2.50
	Floor in contact to ground	0.5	2.00
	Floor over basement	1.33	2.00
	Floor separate two distinct units	1.33	0.75
2.)	Solar floor	1.33	0.75
	Roofs	1.82	0.55
3.)	Windows of main rooms	0.17	6.00
	Windows of main rooms	1.00	1.00

1.) The degree of absorption ≥ 60%, time lag = 6.0h, mass density ≥ 1800kg/m^3
2.) Degree of absorption ≥ 60%, active mass density ≥ 2000kg/m3, thickness ≥ 60mm
3.) With removable thermal insulating shutters or curtains

9.14.6 Climatic Zone III: Minimum Permitted U-Values

Table 18: Mountains (2200m above sea level)

No	Building component	R-Value (m^2.K/W)	U-Value (W/m^2.K)
1.)	External north facing wall	0.4	2.50
	External east/west facing wall	0.5	2.00
	External south facing wall	0.5	2.00
	Wall separating two distinct units	0.4	2.50
	Floor in contact to ground	0.5	2.00
	Floor over basement	1.33	2.00
	Floor separate two distinct units	1.33	0.75
2.)	Solar floor	1.33	0.75
	Roofs	1.82	0.40
3.)	Windows of main rooms	0.17	6.00
	Windows of main rooms	1.10	0.90

1.) The degree of absorption ≥ 60%, time lag = 6.0h, mass density ≥ 1800kg/m^3
2.) Degree of absorption ≥ 60%, active mass density ≥ 2000kg/m3, thickness ≥ 60mm
3.) With removable thermal insulating shutters or curtains

10. BUILDING OPERATION & MAINTENANCE

10.1 Introduction

Buildings - residential and commercial, need upkeep to look their best, maintain a safe environment and serve their intended function and optimal use of energy. The building owners should have a schedule of routine maintenance procedures to perform.

Regular building repair and maintenance might involve replacing a worn doorknob, oiling a squeaky hinge or replacing a damaged floorboard, inspect for burned-out light bulbs and replace them, change the filters in the air conditioning system etc.

10.2 Facility Managers – Commercial Buildings

Usually, all commercial buildings have a facility manager, either as a fulltime job, or as contracted services. The core functions should include

Preventive maintenance - preventive maintenance should be to avoid breakdown of machinery (HVAC Systems, pumps) and equipment on regular basis. Preventive building maintenance includes works to prevent deterioration of building parts e.g. from mildew, insect attack, water damage, heavy usage, accidental damage, and other concerns.

Energy management – one of the co-functions of the facility manager is an energy management program. This is an on-going process that is integrated with routine building maintenance and with any subsequent changes building envelope, occupancy or mechanical equipment. Measurement, monitoring and reporting of energy usage should be part of the functions of a facilities manager.

Energy efficient appliances and equipment - Appliances and equipment used in buildings should be as energy efficient as possible. As technology in this area changes rapidly it is worth investigating the latest energy consumption features and comparing different models in order to identify the most efficient.

11. GLOSSARY OF TERMS

Air conditioning: A system or unit installed in a building to control the temperature and humidity of theair by heating or cooling. Systems may range from a simple package unit installed in the wall of a dwelling, through to a complex integrated system made up of a number of distinct subsystem and components, as found in plant rooms or on the roofs of buildings

Bioclimatic architecture is a way of designing buildings based on the local climate, with the aim of ensuring thermal comfort using environmental resources. They must also blend into their natural surroundings.

Building depth: this refers to the dimension measured from the front to the back of a building's floorplate (as opposed to frontage width). Apartment depth refers to the dimension taken from the glazing line / external wall to the inner-most parallel wall.

Envelope: The external elements of the building, that is walls, windows, roofs and so on.

Glazing: Windows, glazed doors or other transparent and translucent elements including their frames (such as glass bricks, glazed doors, etc) located in the building fabric.

Greenhouse gases: Gases that affect the temperature of the earth's surface. They include water vapour, tropospheric ozone, chlorofluorocarbons, carbon dioxide, methane and nitrous oxides. The lastthree gases are of particular concern because they take a long time to remove from the atmosphere.

Lumens (lm): The units for luminous flux (the light emitted from the light source or luminaire). In regard to the numbering system, the higher the lumen value the brighter the light. The lumen value is obtainable from the manufacturer and may be described as the "lm" value in lighting product literature.

Passive design: a design that does not require mechanical heating or cooling for example buildingsthat are designed to take advantage of natural energy flows to maintain thermal comfort.

R-Value: The measurement of the thermal resistance of a material which is the effectiveness of the material to resist the flow of heat, i.e. the thermal resistance (m^2.K/W) of a component calculated by dividing its thickness by its thermal conductivity.

Shading coefficient: A measure of the solar gain performance of windows. It is the ratio of the solar energy transmitted and convected by the window to the solar energy transmitted and convected by clear 3 mm glass.

Solar access: the amount of useful sunshine reaching the habitable areas of a building.

Solar Heat Gain Coefficient (SHGC): a measure of the amount of solar radiation (heat) passing through the entire window, including the frame. SHGC is expressed as a number between 0 and 1.0. The lower the SHGC the better.

Thermal mass: a term to describe the ability of building materials to store heat . Building materials thatare heavy weight store a lot of heat so are said to have high thermal mass. Materials that are lightweight do not store much heat and have a low thermal mass.

Thermal resistance: The resistance to heat transfer across a material. Thermal resistance is measured as an R-Value. The higher the R-Value the better the ability of the material to resist heat flow.

Thrombe wall: A Trombe wall is a massive equator-facing wall that is painted a dark colour in order to absorb thermal energy from incident sunlight and covered with a glass on the outside with an insulating airgap between the wall and the glaze. It is a building design strategy that adopts the concept of indirect gain, where sunlight first strikes a solar energy collection surface which covers thermal mass located between the Sun and the space. The sunlight absorbed by the mass is converted to thermal energy (heat) and then transferred into the living space.

Ventilation opening: An opening in the external wall, floor or roof of a building designed to allow air movement into or out of the building by natural means including a permanent opening, an openable partof a window, a door or other device which can be held open.

Watt (W) : The determined metric or SI (international system of measuring units) value for energy loadsand is used to rate electrical motors, appliances, lights etc. and in expressing energy loads and energy consumption.

12. REFERENCES

12.1 Annexure 01: SANS 204 (2011) (English): Energy Efficiency in Buildings
12.2 Annexure 02: Lesotho Building Control Act, 1995
12.3 Annexure 03: Thermal Insulation & Energy Efficient Retrofit Guide (TIPSA)
12.4 Annexure 04: National Building Regulation, (Energy Usage in Buildings) of the SANS 10400-XA
12.5 Annexure 05: South African National Standard. Interior lighting Part 1: Artificial lighting of interior. SANS 10114-1. 2005.
12.6 Annexure 06: Building Energy Efficiency Guideline for Nigeria, 2016
12.7 Annexure 07: Design Guidelines for Energy Efficient Buildings in Johannesburg, 2008
12.8 Annexure 08: Inputs from Architects Association of Lesotho

This input requires policy makers to find a way to effectively operationalize the Energy Efficiency Builder' Manual. These inputs are included in this Document since it is not yet a Public Document.

COMMENTS/INPUT ON BUILDERS' MANUAL ARCHITECTS ASSOCIATION

At the outset, the draft manual is a good document that sets out an excellent framework for achieving environmental sustainability goals within Lesotho's built environment. It covers the discipline areas in relation to the professional, construction and supply sectors of the industry enabling all actors within this ecosystem an opportunity to be conversant with Environmental Sustainability concepts and practical solutions.

The most critical element of this manual is the POLICY FRAMEWORK. There needs to be a BOLD commitment by State actors to enact and implement an enabling regulatory environment that will ensure Lesotho's construction industry adopts energy efficient and environmentally sensitive building methods. This will further call for the Ministry of Local Government to deepen Municipal Government through the formation of stronger local councils that will actively regulate the activity of building in all urban centres. At the heart of the success of environmental sustainability is sound urban planning. Lesotho's urban landscape is a chaotic and dysfunctional environment that lends itself to absolutely nothing in terms of socio-economic development, cohesion and quality of life.

There are no positive development outcomes that can be attributed to Lesotho's urban fabric. With Lesotho being a party to the New Urban Agenda 2030, there needs to be significant work that is put into urban and regional planning in order to achieve energy efficiency and environmental sustainability goals. There is very little benefit for the construction industry to adopt energy efficient methods when they will have minimal ripple benefits into the broader built environment through the implementation of zoning, urban greening, building orientation, organization of public transportation and recreational spaces, recycling, renewable power generation and smart water catchment and reticulation to mention but a few interconnected aspects of human habitats.

The regulatory framework needs to re-examine the Government of Lesotho's (GOL) existing building stock. Government buildings need to be benchmark buildings when it comes to energy efficiency and environmental sustainability. Review and enactment of new building codes needs to be immediately followed by the assessment of government buildings in relation to such codes.

GOL Facilities Managers should be compelled to produce building lifecycle management programmes that will ensure compliance of GOL buildings to new building codes, as well as their very positioning in relation to broader urban planning objectives. Without such catalytic programmes spearheaded by GOL compliance to energy efficiency, it will be very difficult to roll out new building codes and construction methods to the general public. The requirement for GOL buildings to exhibit use of Lesotho's sandstone created an industry that serves the broader SADC market. Equally, forced compliance for GOL buildings and prospective rental properties to adhere to new building codes will facilitate the transition of the industry at large into renewables, energy efficiency and environmentally sensitive building methods. Such a catalytic programme will further assist in the reduction of costs of new technologies, enabling them to be available to the individual consumer.

Architects and Engineers are alive to environmental sustainability and the technologies available in this regard. Smart buildings/ automation, Green Architecture and urban planning for inclusivity are concepts that are only available to a few enlightened clients. The key to broadening these concepts into the general built environment lies within a system of sensitive planning, strict regulation, professional implementation and INSPECTION that will ensure compliance, sustainable development and successful mitigation against climate change.

Enactment of the proposed Construction Industry Policy will be a major instrument towards implementation of this Builders Manual. It is a critical ingredient to the strengthening of Lesotho's built environment wherein Continuous Professional Development, Codes of Conduct and Compliance Criteria will work hand-in-hand with building codes and urban master plans to deliver on Lesotho's energy efficiency and environmental sustainability objectives. It is therefore important that State actors recognize their role in realizing the goals of this exercise, by boldly and decisively pursuing the necessary regulatory framework in order for this manual NOT to become one of Lesotho's many lucid programs that have succeeded to gather dust on office shelves.

This draft Builders Manual is a solid document which when implemented can result in far-reaching, positive changes to Lesotho's built environment as well as quality of life of citizens in both private and professional spheres. It requires the removal of inter-ministerial barriers towards a multi-stakeholder system that consolidates human, material and financial resources for *the purpose of boldly reforming Lesotho's built environment for its very survival. As Lesotho faces the brunt of climate change, human settlements need to be ordered, building construction regulated and continually improved in order to ensure continued socio-economic development amidst an increasingly difficult and inhospitable environment.*