



Back to the drawing board

Insulation in buildings: residential homes and commercial buildings



Building energy-efficient homes

1. The role of builders and contractors in improving thermal efficiency in South Africa

In South Africa, the tendency in building properties leans towards the low capital cost side and not energy efficiency. However, a shift in mindset is necessary against the backdrop of the country's electricity shortage and in line with the global drive to find more energy-efficient ways of living and working in order to conserve natural resources and limit the impact of modern-day living on the environment. With electricity costs rising, energy efficiency is also becoming a priority for property and home owners.

Insulation is one of the most important factors for improving the energy efficiency of buildings. Insulated houses stay cooler in summer and warmer in winter and temperatures throughout the home are more uniform. That's because insulation curbs the natural flow of warm air towards cooler spaces, limiting heat losses from the inside and heat gains from outside. An insulated room requires 51% less energy to heat up than one that isn't, and warmth is more effectively retained because insulation prevents the heat generated by heaters from escaping.

Insulation therefore makes the work of heating and cooling systems like heaters and air conditioners much easier. This means that insulation can reduce the energy demand of these systems, which are responsible for a significant share of a household's electricity consumption and costs.

Insulating hot water pipes and geysers also helps conserve electricity because it limits heat loss to the atmosphere while the water is being stored or in transit through the pipes, lessening the burden on the geyser to keep the water at the desired temperature.

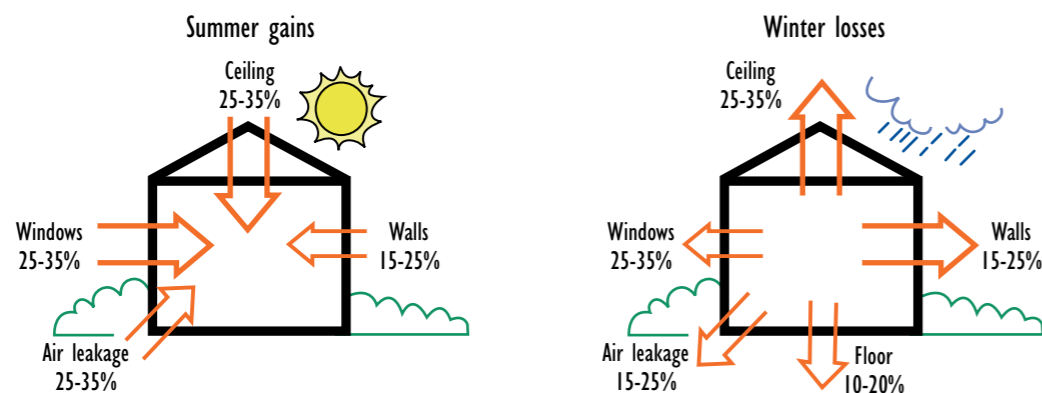
Simply put, a properly insulated building or house requires less energy for heating and cooling, and is therefore energy efficient.

The best time – and easiest way – to insulate a house or building is during construction. Building contractors and project managers therefore have a pivotal role to play in improving thermal energy efficiency in South African homes and small commercial buildings by:

- Encouraging the installation of insulation during the construction phase,
- Providing guidance to homeowners with choosing the most effective solutions to ensure a well-insulated home, and
- Ensuring that insulation applications are correctly installed.

2. Make buildings more energy-efficient

Understanding the role of insulation in improving thermal comfort ensures that requirements are met in the most appropriate and cost-effective way, while ensuring optimal energy efficiency.



The primary purpose of insulation is to reduce heat transfer: Heat losses and gains will happen when two different temperature zones are next to each other. During winter, when the outside temperature is lower than the desired internal temperature, heat transfer takes place from inside the building to the outside, resulting in the interior of the house losing warmth. In summer, heat is transferred from outside, warming up the interior of the house. Similarly, the temperature difference between the water in a geyser and water pipes causes energy flow towards the outside in the form of heat losses.

Insulation helps to minimise the heat transfer rate and keep temperatures constant. Applications that are aimed at keeping heat losses and gains to a minimum include:

- Roof and ceiling insulation
- Geyser blankets
- Hot water pipe insulation/cladding
- Draught-proofing
- Blinds, curtains and shade awnings

A range of materials are used in the manufacture of thermal insulation products:

- Synthetic polymers – polyester, polystyrene, polyisocyanurate, polyurethane, polyisocyanurate
- Mineral wools – fibre-glass, rock wool, slag wool, stone wool
- Minerals – Vermiculite, Perlite
- Natural plant materials – cellulose insulation, cork, hemp, cotton, straw, sawdust and hemlock fibre
- Animal fibres – wool
- Shredded recycled paper chemically treated – cellulose loose-fill insulation

The effectiveness of Thermal Insulation material is rated in terms of thermal resistance, called R-value, which indicates how well the insulation resists heat flow (heat transfer) – or how effective it is in limiting heat transfer in and out of a house or building. Generally, the higher the R-value, the more effective the insulation is. The R-value of thermal insulation depends on the type of material, its thickness and its density.

There are a few factors to consider when selecting thermal insulation:

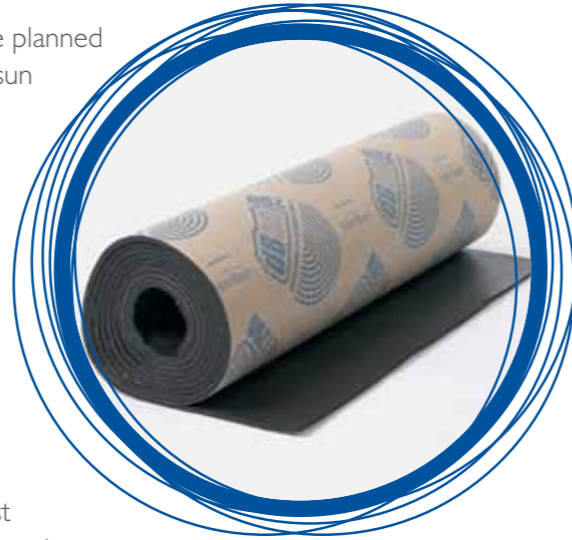
1. Is it in compliance with the relevant South African National Standards applicable to the product?
2. Does it conform to the South African National Building Regulations?
3. Is it appropriate for the intended occupancy or building classification in accordance with SANS 10400 Part A General requirements?
4. Does it comply with the fire safety requirements given in SANS 10400-T Fire Safety and SANS 428 Fire performance classification of thermal insulated building envelope systems?
5. Does the product comply with the recommended R-value for the relevant climatic zones in accordance with SANS 10400-XA Energy usage and SANS 204 Energy efficiency in buildings?

2.1. Design for energy efficiency

Any style of home or building can be designed to be energy-efficient and any existing home or building can improve its energy efficiency. The design of an energy-efficient home or building begins with the decisions made in the early stages of drawing up the plans.

For best results the floor plan and the dwelling/site relationship need to be planned at the same time. The orientation of the building to gain northern winter sun will affect the zoning and relationship of internal spaces, the placement of windows, the location and the layout of major outdoor features, and the planting for sun-shading and wind-screening.

Getting the first steps right means that overall energy efficiency will be easier to achieve. The northerly sun can be harnessed to warm the most frequently occupied areas of a home in the winter and can be easily controlled in summer with the appropriate shading.



2.2. Principles of energy-smart design

There are many factors that contribute to energy-smart design. Some must be dealt with in the planning and design process if they are to be incorporated (e.g. orientation of living areas), while others may be added after construction if necessary (e.g. draught-stripping to doors and windows). Considering 'hard to fix later' factors at the outset is crucial for maximizing energy benefits and lifecycle savings.

While some components of energy-smart design have the potential for greater energy savings than others, overall energy savings depend on their combination and interaction.

The key principles of energy-smart design include:

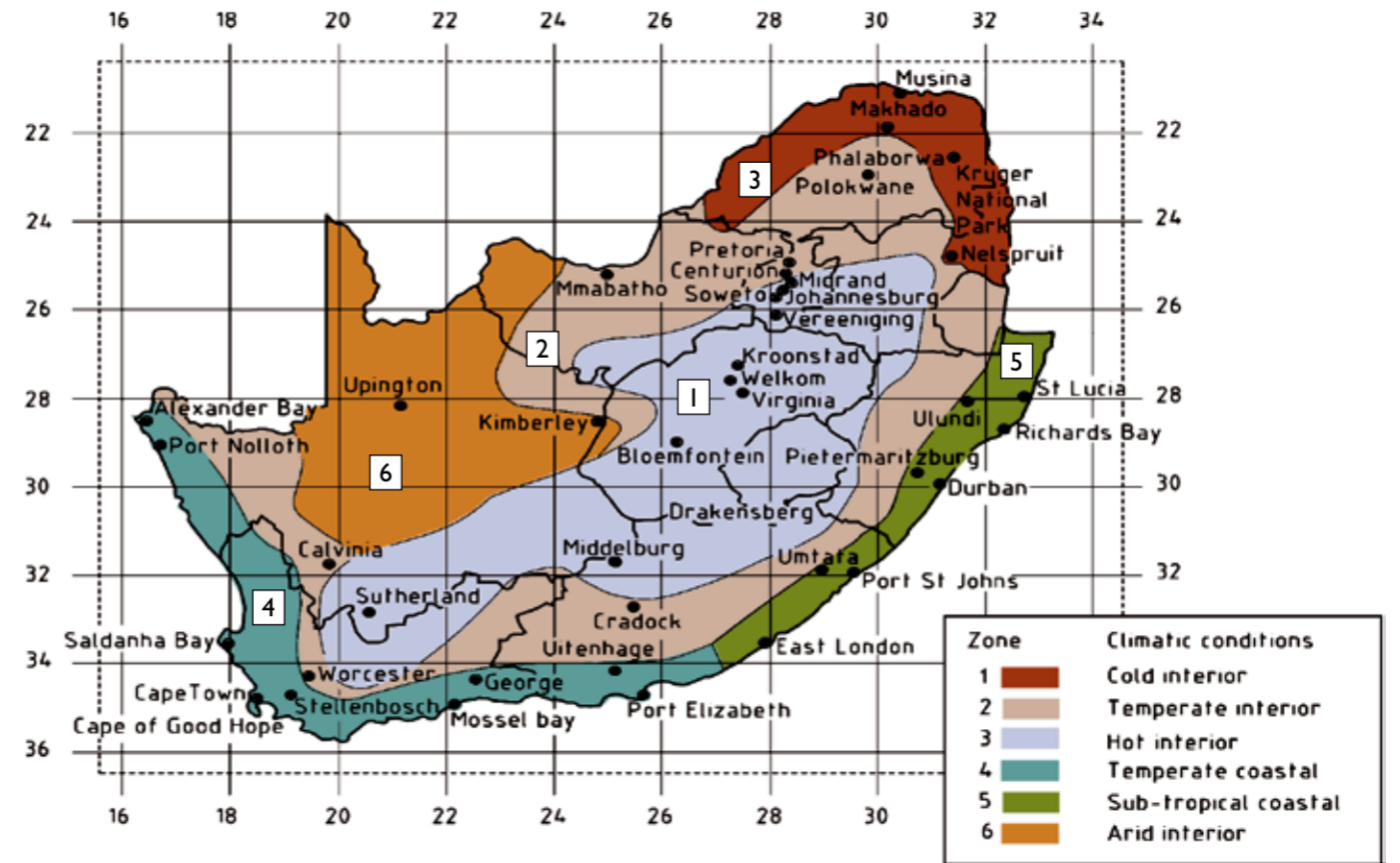
- design for climate;
- appropriate siting;
- orientation - daytime living areas with large north-facing windows to receive unobstructed winter sun;
- internal planning to create zones which reduce the amount of energy required for heating and cooling;
- windows that are appropriately orientated and sized with protection from winter heat loss and summer heat gain;
- adequate thermal mass (building materials) to stabilize indoor temperatures;
- adequate thermal insulation in roofs, ceilings, walls and floors;
- good draught proofing;
- cross ventilation for summer cooling;
- an efficient hot water system and fittings, located close to user station;
- efficient lighting and appliances; and
- landscape design that assists in modifying the microclimate for more comfortable conditions.

2.3. Design for climate

Design for comfort and energy efficiency is influenced by climatic considerations. The map of South Africa is based on six climatic zones. Energy intervention measures will vary from region to region as well as areas within a zone. To achieve the best results, building design and construction materials should be appropriate to the climate of a region.

While each of the six climate zones has different heating and cooling needs, the same principles of energy-efficient design apply, with their application varying slightly, e.g. different levels of insulation or thermal mass or variations in window sizes.

Climatic Zones of South Africa



Zone Number	Description	Major Centres
1	Cold interior	Johannesburg, Bloemfontein
2	Temperate interior	Pretoria, Polokwane
3	Hot interior	Makhado (Louis Trichardt), Nelspruit
4	Temperate coastal	Cape Town, Port Elizabeth
5	Sub-tropical coastal	East London, Durban, Richards Bay
6	Arid interior	Upington, Kimberley

Regional climates make for different insulation requirements. In cold conditions, the imperative is to reduce heat flow out of the building, while in hot conditions the goal is to reduce heat transfer from outside.

In very hot or very cold climates – where temperatures outside are very different to desired internal temperatures – more insulation will be required to help keep temperatures inside the house constant and ease the burden on heating, ventilation and cooling systems (HVAC).

The insulation strategy of a building must be therefore based on a careful consideration of the mode of energy transfer, its intensity and the direction in which it moves. This may alter throughout the day and from season to season. It is important to choose the correct combination of materials and techniques to suit the particular situation. If refrigerative air conditioning is employed in a hot, humid climate, it is particularly important to seal the building envelope. Dehumidification of humid air infiltration can waste significant energy.

2.4. Building orientation

Choose a site with good orientation for your climatic and regional conditions. Build or renovate to maximize the potential and to achieve the best possible orientation for living and working areas. Poor orientation can exclude winter sun, and cause overheating in summer by allowing low angle east or west sun to strike glass surfaces.

2.5. Orientation sectors

Correct orientation to achieve a high level of unobstructed winter sunshine is essential. A house or building should be designed to respond to site conditions to maximize free solar access and energy. Solar access refers to the amount of the sun's energy available to a building. Good solar access means reduced energy requirements, improved comfort levels and environmental benefits.

All forms of housing, including medium and high density housing, can save significantly on energy use for heating and cooling if solar access is good. Where possible, choose a site that can accommodate north-facing daytime living, working areas and outdoor spaces.

2.6. Budget and personal preference

The owner of the building or homeowner's budget will influence insulation choices. There are a lot of variables that impact the cost of insulation as the price of materials and cost of installation can vary greatly. It is most cost-effective for insulation to be installed during the construction of the house or building, as insulation is generally hidden and parts of the building may need to be deconstructed. This leads to increased costs. Retrofits, although common, are therefore more expensive.

Improving the energy efficiency of a home or building with effective insulation, while requiring some capital outlay in the beginning, is cost-effective in the long run because it results in lower energy consumption and costs. Furthermore, insulation has minimal recurring expense because, unlike HVAC systems, it doesn't require regular maintenance or adjustment.

Building project managers and contractors should discuss the available insulation methods and applications with their clients and provide price and performance comparisons so that the homeowner can make informed decisions.

3. Insulation applications for South African homes and small commercial buildings

There is a wide array of insulation products, applications and methods for improving the thermal insulation in a building.

3.1. Where and how much?

The level of insulation will depend on climate zone, building construction type, and whether auxiliary heating and/or cooling is used.

Ceiling insulation is by far the most effective way of insulating a home or building in order to reduce heat penetration in summer and prevent heat generated by heating systems from escaping during winter.

In accordance with SANS 204 Energy Efficiency in Buildings a roof system will achieve the minimum total R-value specified in Table 1 for the direction of heat flow.

The direction of heat flow in Table 1 is considered to be the predominant direction of heat flow for the hours of occupation of the building. It takes into account the higher rate of occupancy of houses at night time rather than day time.

Where "downwards" is specified in Table 1, this indicates summer heat (a downwards heat flow into the building) is the major concern. A combined downward and upwards requirement means that summer and winter (heating and cooling) have a roughly similar level of energy use on an annual basis, while an upward flow indicates that heat loss from the building during winter is the major concern.

In hot humid climates where buildings are naturally ventilated, high down R-values and low up R-values are appropriate for roofs and ceilings.

Table 1: Minimum required Total R-value (m².K/W) for Roofs (SANS 204)

Climate zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Minimum required Total R-Value (for roof solar absorption of more than 0.55)	3.7	3.2	2.7	3.7	2.7	3.5
Dominant direction of heat flow	Upwards	Upwards	Down and Upwards	Upwards	Downwards	Upwards

Note: Condensation could occur in three areas; the cold interior (Climatic Zone 1), the temperate interior (Climatic Zone 2) and the temperate coastal area (Climatic Zone 4), therefore vapour barriers, adequate ceiling insulation and roof ventilation must be provided.

3.2. Types of insulation

There are various types and brands of thermal insulation available on the local market.

Generally insulation is divided into three categories:

1. Bulk insulation
2. Reflective foil insulation
3. Composite bulk insulation

Bulk insulation mainly resists or slows down the transfer of heat by conduction and convection, relying on pockets of trapped air or low conductive gasses within its structure. Its thermal resistance is essentially the same, regardless of the direction of heat flow through it. For bulk insulation, R-values are provided for a specific thickness and density of material at a given temperature. The thicker the insulation material, the higher the R-value for that product. Bulk insulation traps air in still layers. The air does the insulating - the material simply traps it, slowing down or lowering the transfer of heat or heat transfer.

Bulk insulation includes materials such as glass fibre, slag wool, rock fibre, cellulose fibre, polyester fibre, polystyrene, polyurethane and polyisocyanurate. Each product has a material R-value for a given thickness, density and temperature.

3.2.1 Types of bulk insulation (Batt Blanket & Matt Insulation)

Glass Fibre (Glasswool) manufactured from molten glass spun and formed into mats, rolls and blankets of fine fibres coated with a binding resin. Batts and blankets are lightweight, fit standard tie beams and stud spaces and are easy to cut and install. Should not be compressed or moistened. Butt all ends and edges together firmly. If installed carefully it will not slump or settle. During installation glass fibre can cause eye, skin and respiratory irritation, and manufacturer's safety recommendations should be followed. Maximum limited operating temperatures are at 350°C.

Mineral Wool (Slag/Rock Wool/Stonewool) manufactured from molten industrial slag, that is fiberized, treated with oil and binders to suppress dust, and maintain shape. It is similar to glass fibre in texture and appearance, but denser than glass-wool so R-Value per unit thickness is higher. Rock Wool is manufactured in a similar manner, except that natural rock is used instead of slag. These materials have a high fire resistance, limiting maximum operating temperature to 850°C. Generally rock wool is more expensive than glass wool. It can cause eye, skin and respiratory irritation during installation.

Polyester Fibre made from polyester fibres (including recycled PET bottles) spun into a flexible mat. The product is available as batts or blankets. It is easy to cut and install, non-irritable, with no known physical or health hazards. When exposed to a direct flame the product will melt and shrink away from the flame. Maximum limited operating temperature is 150°C.



Cellulose Loose Fill Insulation

Cellulose Fibre insulation is made from finely shredded recycled paper that is milled into a light fibrous matrix, which is chemically treated to resist fire and fungal growth. Due to the small size of the particles, cellulose can 'flow' around obstructions (nails, electrical wires, trusses, etc.) to give a uniform fill. If the insulation is not blown to manufacturer's recommended, density and thickness it can settle over time, and the intended R-value will not be achieved and maintained. Blown cellulose can be installed in vertical wall cavities using a variety of specially designed, reinforced interior sheeting products.

Rigid Board Insulation

Vermiculite is a mineral closely related to mica that expands when heated to form a lightweight exfoliated material with insulating properties. There are two types of **vermiculite**: untreated and treated. The treated material is coated with asphalt to make it water-repellent, for use in high moisture areas. Untreated vermiculite absorbs water and, once wet, dries very slowly. Vermiculite is usually hand-installed, and is suitable for both horizontal and vertical applications. It is non-combustible, odourless and non-irritating, although due to its high density it is not usually the material of choice where a high R-value is desired.

Expanded Polystyrene (EPS) is a lightweight, plastic foam insulation produced by trapping small amounts of pentane gas into solid beads of polystyrene. The pentane gas expands under the action of heat, applied as steam, to form perfectly closed cells of EPS. These cells occupy approximately 40 times the volume of the original polystyrene bead. The EPS beads are then moulded into blocks or boards in three standard densities. EPS has excellent thermal properties, is moisture resistant, and provides environmentally safe lifetime durability. EPS StyFRene is fire retardant. EPS is easy to install, non-toxic, contains no CFCs or HCFCs and is recyclable.

Extruded Polystyrene (XPS) is a closed cell polystyrene foam board, which retains gas but excludes water. It is produced on a continuous, fully automated extrusion process. It is manufactured in two densities. The high density board should be used where the material will be exposed to relatively high pressures, such as below a concrete slab or in built-up roofing. Most commonly used for slab edge and cavity brick wall insulation. Polystyrene will 'break down' if left exposed to sunlight for prolonged periods, and must also be protected from solvents and non-compatible adhesives.

Polyurethane and Polyisocyanurate insulations are manufactured by chemical reactions between poly-alcohols and isocyanurates creating or forming tiny air cells. The cells contain refrigerant gases (fluorocarbons) instead of air. The boards are usually double-faced with foil, or sometimes come bonded with an interior or exterior finishing material. The boards must be protected from prolonged exposure to water and sunlight and, if used on the interior, must be covered with a fire-resistant material such as drywall. Due to the relatively high cost of these insulations, use is generally limited to areas which require a high R-value but where space is very limited.

Phenolic Foam is manufactured from phenol formaldehyde resin, and is available as either an open or closed cell product. The boards usually come with a foil facing on one or both sides. It is much less combustible than other rigid insulations. It should be protected from prolonged exposure to sunlight and water. It is suitable for wall sheathing, and for use on the interior, both above and below grade. Use is generally limited to areas which require a high R-value, but where space is very limited.

Spray Foam Insulations

Polyurethane Foam is closed cell foam, usually pale yellow in colour, that can be used for a variety of spray applications. The material is mixed on site with special equipment for large applications. For small applications, single component foam is available in spray cans, for sealing around windows, doors, etc. The foam will act as an air barrier, but not a vapour barrier and should be protected from prolonged exposure to sunlight. When the foam is used in the interior of a house, it must be covered with a fire-resistant material, such as drywall.

3.2.2 Reflective Foil Laminates (RFLs)

Reflective Foil Insulation (Radiant Barrier products) mainly resist radiant heat flow due to their reflectivity, low radiant heat absorption, and low emissivity (ability to re-radiate heat). Reflective insulation is usually shiny aluminum foil laminated with reinforcements or low-density polyethylene bubble encapsulated with air and laminated to foil and are supplied in rolls.

Reflective insulation is more effective at reducing summer heat gain than reducing heat losses in winter and this should be taken into account at design stage. RFLs relies on the presence of a defined air space next to the shiny surface. The thermal resistance of reflective insulation varies with the direction of heat flow through it, i.e. either vertical, horizontal or at a slope. The system R-values for reflective foil insulation are stated as being either up or down values.

The reported system R-values are tested at a given air space thickness and air temperature. System R-values depend on where and how the reflective insulation is installed. Users should ensure that the system values provided by the manufacturer relate to the particular installation situation.

3.2.3 Composite bulk insulation

Composite bulk and reflective materials are available that combine some features of both types. Examples include Foil bonded to bulk insulation, whether blankets, batts or boards, i.e. foil-faced blankets, foil-faced batts and foil-faced boards.

3.3. Recommended levels of insulation

The deemed-to-satisfy (DTS) recommended levels of insulation can be achieved by the use of reflective foils, bulk insulation or rigid board insulation, individually or in combination with one another. Maximum efficiency may be achieved at reduced thicknesses taking the aforementioned into account. Rational design is always an alternative to DTS provisions.

Example of deemed-to-satisfy required thicknesses of generic insulation products								
Description			Climatic zones					
			1	2	3	4	5	6
Generic Insulation Products	Density kg/m ³	Thermal Conductivity W/(m.k.)	Recommended deemed-to-satisfy minimum thicknesses (mm) of insulation product					
Cellulose Fibre Loose-Fill	27.5	0.040	135	115	100	135	100	130
Flexible Fibre Glass Blanket	10-18	0.040	135	115	100	135	100	130
Flexible BOQ Polyester Fibre Blanket	24	0.038	130	110	90	130	90	125
Flexible Polyester Blanket	11.5	0.046	160	140	120	160	110	150
Flexible Mineral / Rock Wool	60-120	0.033	115	100	80	115	80	100
Flexible Ceramic Fibre	84	0.033	115	100	80	115	80	100
Rigid Expanded Polystyrene (EPS)SD	15	*0.035	120	100	90	120	80	115
Rigid Extruded Polystyrene (XPS)	32	*0.028	100	80	70	100	65	90
Rigid Fibre Glass Board	47.5	0.033	115	100	80	115	80	100
Rigid BOQ Polyester Fibre Board	61	0.034	115	100	80	115	80	110
Rigid Polyurethane Board	32	*0.025	85	70	60	85	60	80

Note 1: Thermal Conductivity used for calculation of recommended thicknesses of insulation materials as per TIASA Protocol for Routine Testing for naturally ventilated buildings. *Thermal efficiencies are dependent on material thickness, density, age, operating temperature and moisture. Thicknesses are rounded up to nearest production standard. This is a guideline for general design purposes. For critical design purposes; i.e. rational design, contact manufacturers for actual R-values (Thermal Resistance (m²K/W)) and valid test reports, refer to ISO 10456 Building materials and products – Hygrothermal properties – Tabulated **design values and procedures for determining declared and design thermal values.**

Note 2: The aforementioned deemed-to-satisfy recommended levels of insulation could be achieved by the use of reflective foils, bulk insulation or rigid board insulation or in combination with one another. Maximum efficiency may be achieved at reduced thicknesses taking the aforementioned into account. Rational design is always an alternative to deemed-to-satisfy provisions.

Note 3: Actual R-values for roof construction systems are established through testing in accordance with ASTM C1363 Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus with SAFIERA. Specifiers are encouraged to obtain these test results.

3.4. Geyser insulation

Hot water heating accounts for between 30% and 50% of an average household's electricity consumption and costs.

Geyser blankets can help to reduce the amount of electricity a geyser uses. Insulation slows down the cooling rate of a geyser when it is switched off. It also helps reduce heat loss to the atmosphere while water is being stored in the tank. This means that less electricity is needed to keep water at the thermostat temperature or reheat the water after the geyser has been switched off.

Tests have shown that geyser blankets save 20% of the 2.59kW/h of electricity required to reheat the water in a geyser that's been off for 24 hours. A geyser covered by a geyser blanket is not at a higher risk of overheating, exploding or catching fire, provided the correct materials are used. By insulating a geyser, heat losses are reduced, easing the burden on the geyser, reducing energy costs and increasing the availability of hot water.



The installation of geyser blankets can be tackled as a DIY project. It is very important to cover the geyser properly and to ensure the blankets are secured properly. The best time to install a geyser blanket is before the installation of a new geyser or with the replacement of an old one. This makes it easier to ensure quality workmanship.

Geyser blankets are manufactured using the same materials used in ceiling insulation. Blankets usually come with all the necessary tape and ties to complete the installation. When wrapping an installed geyser with a geyser blanket, it is necessary to cut the blanket to fit around the pipes and legs of the geyser.

3.5. Hot water pipe cladding

Hot water pipe cladding or insulation significantly reduces heat losses to the atmosphere while hot water is in transit to outlets and taps. Ideally, all hot water pipes should be insulated within 1 metre of the connection to the heating or cooling system.

There are a number of suppliers and installers that have specialised products which are designed to quickly and efficiently insulate a wide range of pipe sizes and types. Some types of ceiling insulation can also be used to clad hot water pipes, using duct tape or cable ties to secure the cladding to the pipes.

3.6. Draught-proofing

While adequate controllable ventilation is essential to provide fresh air, prevent condensation, and help cool a building on summer nights, draughts can create discomfort and lead to energy losses in both summer and winter.

In winter, draughts can account for up to 25% of heat losses. Reducing these draughts can be a cheap and cost-effective way of reducing heating and cooling costs.

New buildings should be built to minimize draughts, by avoiding gaps at construction joints between different wall materials, and where walls join or meet the ceiling and the floor, and by ensuring that doors and windows fit snugly in their frames.

Caulking and weather-stripping are the best means of sealing cracks and holes in and around a house or building. Common areas that require insulation or draught-proofing include:

• Doors and windows

Windows and doors should close properly to prevent air leakage into and out of the building. Windows and doors that do not shut tightly should be sealed. Foam tape of different thicknesses can be used to seal window frames and doorframes. Foam tape has a self-adhesive surface that is attached to the frame. Closing the door or window compresses the foam and serves as an efficient air seal.

Door "snakes" (tubes filled with sand) can also be used as effective seals to stop cold or hot outside air from entering the home under the doors. Aluminium door skirts with rubber seals that are screwed to the outside of the doors are also available and act as an effective air and water seal.

• Walls

The cavities in and between bricks act as thermal bridges and should be caulked or sealed to prevent unwanted heat loss and gain and improve thermal insulation. Gaps between bricks can be filled with polyurethane. It is best to seal walls before the final coat of paint is administered to the building.

• Chimneys

The best way to seal a chimney is to have a damper installed that is closed when the chimney is not in use. If the chimney is not utilised at all, it should be sealed off at the top and bottom.

3.7. Blinds, curtains and shade awnings

In hot conditions, the greatest source of heat energy is solar radiation. This enters buildings directly through windows. Windows are also a source of heat transfer from the inside of the building to the outside.

Window blinds and curtains also improve thermal insulation by acting as a barrier across glass windows and preventing heat from leaving and entering the home. Shade awnings can dramatically reduce radiant heat from the sun entering a home. Double glazing can also be employed to reduce heat gains from solar radiation.

The construction industry has an important role to play in improving the energy efficiency of new properties simply by making insulation part of the design process. Prior to the actual construction of the house or property, clients should be advised on the insulation options available to them so that they can insulate the desired spaces during the building process itself, thereby saving themselves money in the long term.

Further information is available from the Thermal Insulation Association of Southern Africa (TIASA) on their website www.tiasa.org.za or, to log a query for an energy advisor in your area to contact you, call the Eskom Contact Centre on **08600 ESKOM (08600 37566)** or visit www.eskom.co.za/dsm for information on energy-efficient technologies and adaptations.



Issued by Eskom Demand Side Management June 2010
Eskom Holdings Limited Reg No 2002/015527/06