handbook on passive design strategies for energy efficient buildings

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Foreword

The contents of this handbook is based on experience gathered during project implementations, training activities, capacity building and conduction of seminars on energy efficiency. It was gathered that energy efficiency in buildings can be fully achieved by applying appropriate design of the building itself, including areas such as orientation, shading, glazing and insulation of walls and roof.

This handbook is to provide guidance on good practices for the planning and design of architectural works in buildings with compliance to the requirements of the relevant provisions in the National Green Technology Policy, The National Standards MS 1525:2007: Code Of Practice On Energy Efficiency And Renewable Energy For Non-Residential Buildings and other international standards. The Government believes this is the way forward towards a sustainable environment in a coherent and integrated manner so as to ensure a brighter world for our future generations.

This handbook is produced in the hope that it will assist architects and designers in making appropriate decisions during the planning and design process so that an integrated design can be achieved with energy efficient features that contributes towards sustainable developments.

Public Works Department Malaysia

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1.0 General

1.1 Background

Nowadays, there has been much talk about the need to adopt and embrace sustainable development and green technology best practices. In conjunction with the 10th Malaysia Plan, the Government has come up with the goals concerning green technology. As mentioned by Prime Minister, Dato' Sri Mohd Najib bin Tun Abdul Razak, the time has come for Malaysia to go green.

In year 2006 budget presentation, the former Prime Minister,Tun Abdullah Ahmad Badawi announced that the Government is paying about RM1.5 billion on electricity bills each year for government buildings. In response to this he urged government agencies to make a savings of at least 10% of this figure.

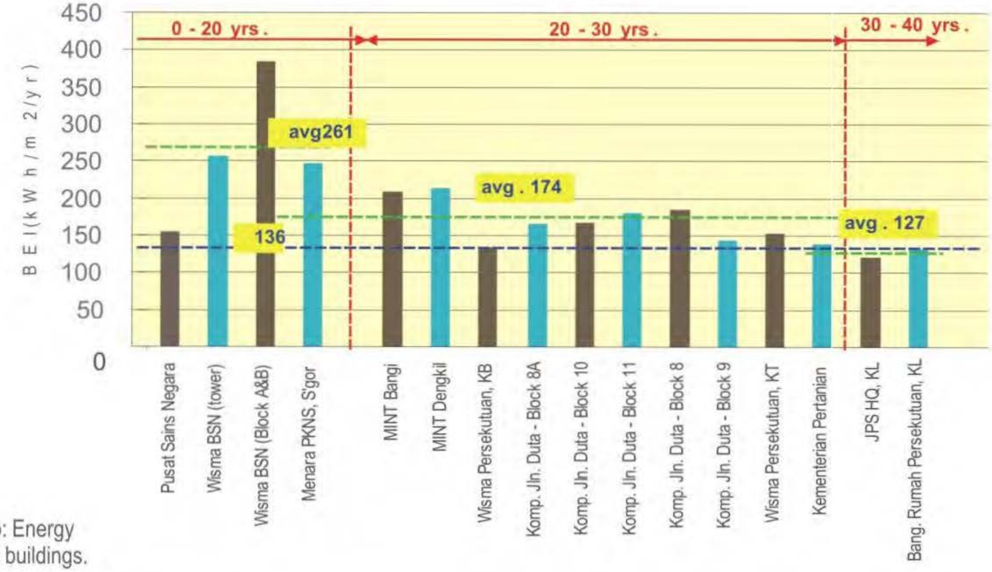


Figure 1: Current building scenario: Energy audit findings of some government buildings.
Source: PTM, 2006

Therefore, as JKR is the government's main implementing agency, it is crucial to address energy efficiency right from the design stage. This handbook is designed to assist and also guide architects in designing an energy-efficient building and also to enlighten them on issues that need to be addressed in the active design part.

In 2006, Pusat Tenaga Malaysia conducted energy audits in 16 government establishments. It was learnt through this exercise that the average energy consumption index varies between older and newer buildings. Refering to Figure 1, buildings built between 30 to 40 years ago only possessed an average energy intensity of 127 kWh/m²/year. Whereas, buildings built more recently possess an average energy intensity of 261 kWh/m²/year.

" They will be promotion, education and information dissemination to create the buy-in of the public to support the 'green economy' and adopt the 'green practices' as part of their lifestyle. Under this thrust, the Government will lead by example by adopting Green Technology in government facilities..."

Prime Minister,
Dato' Sri Mohd Najib
bin Tun Abdul Razak, 2009

This may probably be due to more so-called sophisticated designs of buildings and other energy-consuming requirements. This may also be due to the style of architecture that architects have adopted over the the past few decades. The use of curtain walling, less than practical sunshading devices and materials specified may also be contributor to this phenomenon.

1.2 Problem Statements

- there is no specific document produced as a guide for JKR architects to follow when designing an energy-efficient building
- passive design strategies are not considered important when an energy-efficient building is designed
- current preliminary findings show that building owners/client ministries and departments are still reluctant to adopt Energy Efficient concepts due to obstacles in departmental policy, technical and financial aspects. Therefore, increasing knowledge and awareness in these specific areas is crucial to overcome these barriers

1.3 Objectives

- this guidebook aims to increase awareness among designers to create sustainable living spaces with the intent of conserving energy resources
- to optimise the energy efficiency of a building by having an integrated approach to architecture, engineering, site planning and landscaping
- to design within contextual climate and site
- to extend our resource base and protect the environment, thus ensuring the quality of life for future generations.

1.4 Energy Efficiency Overview

By designing buildings and landscaping which minimise environmental impact and by constructing them from components making efficient use of resources, the building industry and its customers may take immediate and practical steps to facilite new development while placing less stress on our regional and global resources.

Figure 2: Shading can be provided by building elements such as awnings, overhangs, corridors and trellises.
Source: Cawangan Arkitek, JKR

In general, an energy-efficient building is linked to the concept of "sustainability," which is defined as "...meeting the needs of people today without destroying the resources that will be needed by persons in the future; based on long-range planning and the recognition of the finite nature of natural resources..." (United Nations' World Commission on Environment and Development).

Specifically, green building refers to energy and material efficiency. It must take into account the natural resources used to cool and make materials as well as resources to process, transport, install, maintain and, ultimately, dispose of the built environment.

Basic rules to optimise the energy efficiency of a building :

- combined architectural, engineering, site planning and landscaping approaches
- to design within contextual climate and site
- passive design strategies supplemented with carefully designed active systems

Figure 3: The Headquarters of the Energy Commission of Malaysia, Putrajaya is designed to reduce building energy consumption.
Source: http://www.skyscrapercity.com/

2.0 Passive Design Strategies

Passive design is an approach to building design that uses building architecture to minimise energy consumption and improve thermal comfort. It is also known as "climate adapted design" or "climate responsive design", which takes optimal advantage of the surrounding environment without significant extra cost and effect by responsiveness to the immediate environment.

The building form and thermal performance of building elements (including architectural, structural, envelope and passive mechanical) are carefully considered and optimised for interaction with the local microclimate.

2.1 Building Orentation

Building orientation can have an impact on lighting and cooling costs. The basic rule is to avoid direct sunlight entering into the building while providing viable possibilities for daylighting. This can be achieved by taking into account the following criteria (see Figure 4):

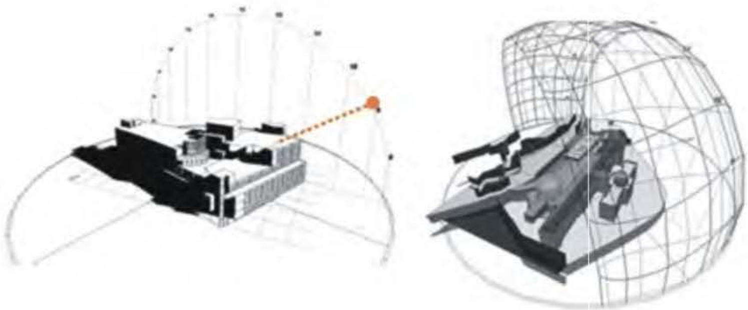


Figure 4: The basic rule of building orientation is to avoid direct sunlight entering into the building while providing viable possibilities of dayligthing.
Source: IEN Consultant

- main facades (if possible) should face north/south. East/west facing facades should be minimised
- if the site is not suitable for north/south facing facades:
  - openings facing east/west must be carefully designed
  - shading means and devices for openings must be incorporated
  - east/west facing façades must be protected with extra insulation or landscaping
- building longitudinal orientation should ideally be on an axis 5°north-east
- orientation of building form will contribute to the shading ofadjacent open spaces, which will affect the internal space
- microclimate information (ie. temperature, wind direction, **precipitation* etc.) must be analysed to help with building form

* ***precipitation*** *is rain, snow, sleet, hail, and other forms of water falling from the sky*

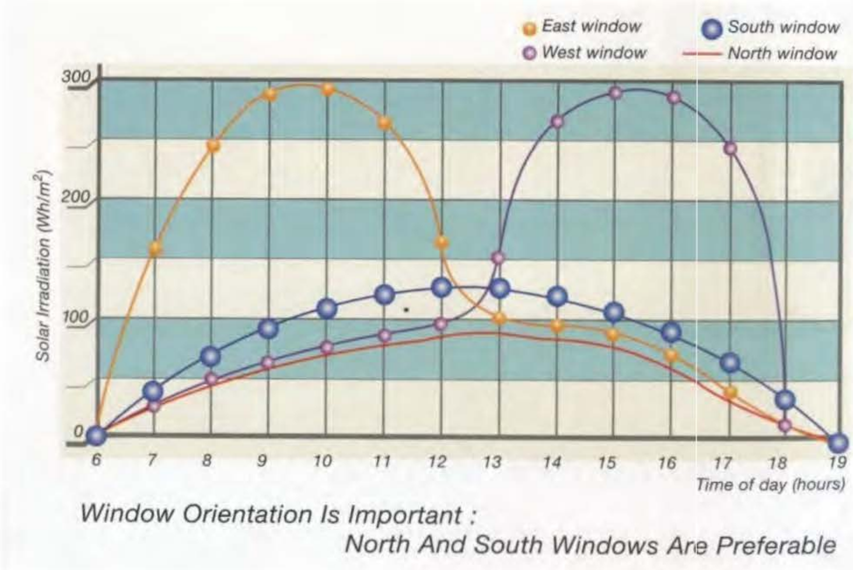


Figure 5: In tropical countries, it is best for the main facades of a building to face the north and south to reduce the direct absoption of heat from the sun.
Source: Kementerian Tenaga, Air dan Komunikasi (2004)

2.2 Facade Design

The materials by which building's facade is constructed are a key element, not only to its beauty but also to its practicality. Good facade design allows the building to look beautiful from the outside and to save the owner money when it comes to cooling (refer Figure 6). The choice of materials for façade design can help minimise solar heat gain. The design of wall and fenestration systems in the façade should be an integrated solution to provide:

- view
- daylight and glare control
- aesthetics ~ building image
- maintainability

A building's facade system should have a high thermal performance. This means that because the facade system helps the building gain less heat, the air-conditioning system is subject to a lower load. Since the air-conditioning system accounts for a significant portion of a typical building's electricity bill, having a facade system that facilitates good thermal performance has a direct impact on energy consumption.

Figure 6: Special care is required for windows that are facing east or west, to reduce the cooling load of the building and to maintain visual comfort.
Source : Cawangan Arkitek JKR

2.3 Strategic Landscapes

Figure 7: Example of trees around a building.
Source: Cawangan Arkitek, JKR

Many landscape considerations occur very early on in the design process. Setbacks, street trees, street alignment and use of landscape buffer zones can be guiding elements of many site planning decisions. Therefore, careful consideration of landscaping is critical to successfully implement the passive approach at the early stages of design. Designers must also recognize the value of the existing soil and plants on site and work with them.

Vegetation can help in many ways:

- reducing ambient temperature and limiting the heat island effect around buildings, thus reducing the cooling load
- protecting the building from sun and precipitation
- reducing solar intensity received by walls and roof by introducing vegetation 'green' roofs and walls

Surrounding vegetation will provide a milder temperature zone around a building. Hence, less energy is needed to cool the building. Strategic landscaping may be used to reduce heat gain through:

- shading of direct exposure to east and west facing facades (refer to Figure 7)
- creation of a cooler microclimate around the building (refer to Figure 8)

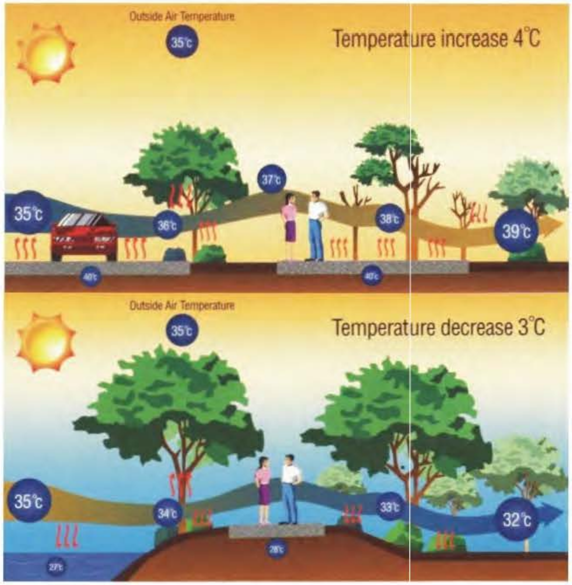


Figure 8: The Cooling Effect of Greenery.
Source: Professor Dr Soontorn, Bangkok

Effective strategies for landscaping :

- identify existing mature trees and plan accordingly to minimise cutting felling
- maximise the softscape and keep it permeable so that surface water run-off is minimised
- provide at least 20% of the total site area with landscaping
- green roofs and green walls can be used to meet this requirement (Figure 9)

Figure 9: Green roofs offer various possibilities for usage, including: natural refuges for insects and plants, recreational roof gardens, roof cafés and sporting areas.
Source: Ivy Exchange, Dublin

- choose appropriate high *albedo** materials (high reflective and high *emissivity*** paving or roofing materials) to reduce heat gain
- incorporate aquascape, wherever possible
- keep hard surfaces away from building

A combination of high albedo materials (high reflective and high emissivity paving or roofing materials) and landscaping can be provided to achieve the 20% needed for landscaping.

Further initiatives in keeping energy consumption low :

- lower heat gain through roof ~ green roof, roof garden
- shading of external air-conditioning
- condensers to maximise efficiency cooler microclimate

* ***albedo*** *of an object is the extent to which it diffusely reflects light from light sources such as the sun*

** ***emissivity*** *of a material (usually written ε or e) is the relative power of its surface to emit heat by radiation*

Designing projects to work harmoniously with the site is essential to achieving substantial energy and water efficiency and their associated cost savings. Design buildings so that indoor and outdoor spaces are as comfortable as possible without the need for extra cooling. Save space on site for outdoor space and natural features, and save resources and money while doing so.

Green Roofs

A green roof is a roof of a building that is partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane (refer to figure 10 & 11).

Green roofs can be used for rainwater retention to increase thermal resistance and capacitance of a roof assembly, to reduce the urban heat island effect, and/or to provide a habitat for animals or an amenity for people on what would otherwise be a hard-surfaced unused area.

Figure 10: Green roof cross section
Source: American Wick Drain Corp

Figure 11: Successful green roofs require a building massing that permits appropriate solar exposure for the intended types of vegetation.

Shading from adjacent buildings or trees may produced a significant impact on the successful growth of rooftop plants. Building massing can also be used to create rooftop surfaces that are relatively protected from wind.

If it is also accessible to building occupants, greater integration of the green roof with appropriate interior spaces is desirable. Structural system design, careful detailing of drainage systems, irrigation systems, and penetrations of the roof membrane are key concerns.

Building form will also determine how building occupants can interact with a green roof. A green roof is a user amenity only if it is at least visible to occupants.

2.4 Space Planning

Matching the space requirements with orientation and massing (building geometry) may further decrease energy use and increase thermal comfort. Building functions with particular thermal requirements should be placed in areas of the building that can provide such conditions (or approach these) without mechanical intervention (see Figure 12 - 17). The important factors that should be considered include the following:

- locating spaces in their ideal thermal location in the building, e.g. stores, toilets, services may be located on the east/west side of the building
- no intense (deep) planning
- have smaller courtyards
- have a more open concept offices/areas nearer to the façade of the building

- effective room depth ~ fingerlike designs
- transparent internal partition walls
- light-coloured walls and ceiling
- effective floor to ceiling height

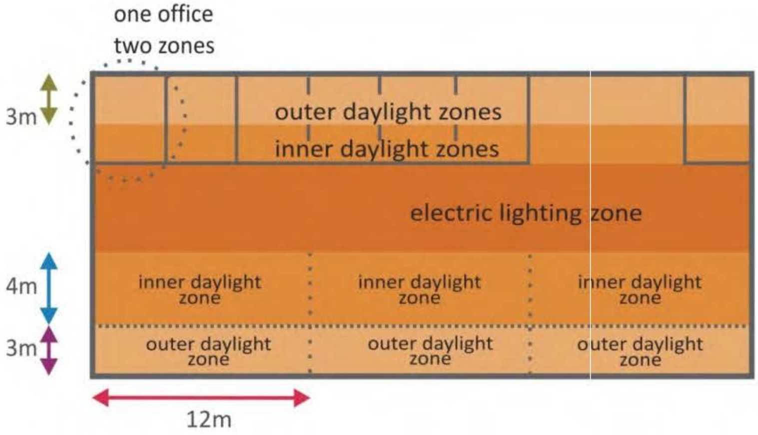


Figure 12: In the generic diagram of floor in an office building, the requirement for separate lighting circuits is shown.
Source: Kementerian Tenaga & Komunikasi (2004)

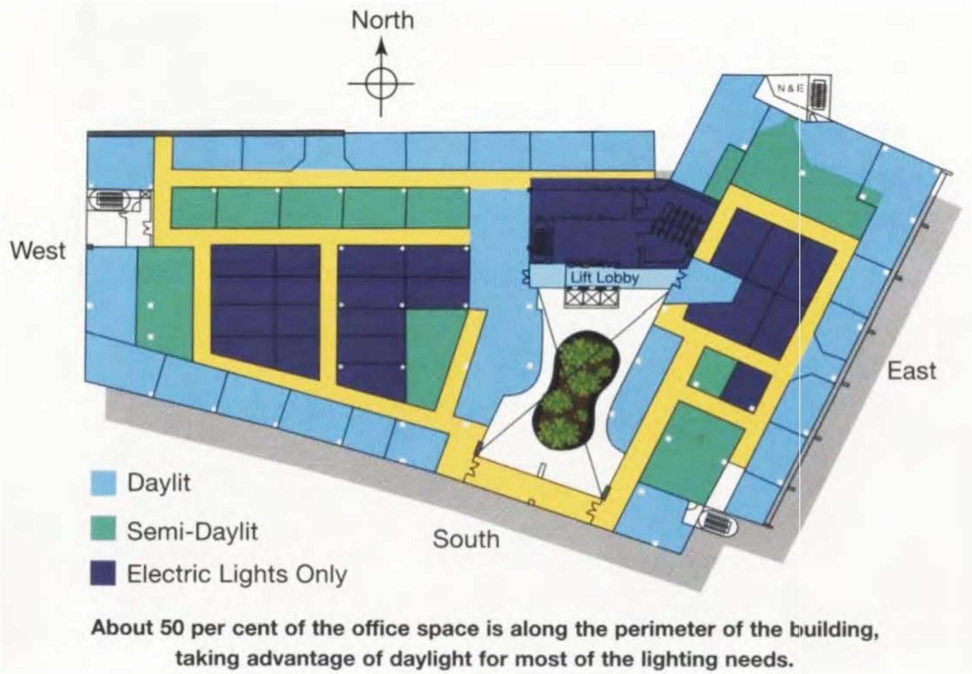


Figure 13: Space planning principle.
Source: Low Energy Office, Kementerian Tenaga, Air & Komunikasi (2004)

Figure 14: Shading devices can also be used as light reflectors (sometimes called light shelves), that bounce natural light deep into building interiors.
Source : IEN Consultant

Figure 15: Transparent walls allow daylight as a light source in buildings.
Source: IEN Consultant

Figure 16: Effective room depth – fingerlike designs
Source: Cawangan Arkitek JKR

Figure 17: Internal Courtyard
Source: Cawangan Arkitek JKR

2.5 Ventilation

Building ventilation is the circulation of air throughout a building. There are two methods of providing ventilation as shown in Figure 18 :

- cross ventilation
- stack ventilation

Air movement increases comfort limit. Areas encouraged to be naturally ventilated :

- lobby areas
- corridors
- lift cores
- staircases

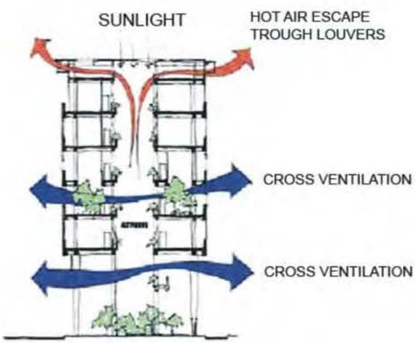


Figure 18: Cross ventilation diagram.
Source: IEN Consultant

Cross Ventilation

Cross ventilation establishes a flow of cooler outdoor air through a space; this flow carries heat out of a building. Cross ventilation is a viable and energy-efficient alternative to mechanical (active) cooling under appropriate climate conditions.

The effectiveness of cross ventilation is a function of the size of the inlets, outlets, wind speed and outdoor air temperature.

Figure 19: Louvres can maximise natural ventilation and the most efficient ventilating window available that allow us to control airflow and light.
Source: http://www.flickr.com/

Figure 20 & 21: The greater the air flow, the greater the cooling capacity.
Source: Cawangan Arkitek, JKR

Successful cross ventilation requires:

- a building form that maximises exposure to the prevailing wind direction, providing for an adequate inlet area
- avoidance of external obstructions to wind flow (such as trees, bushes, or other buildings)
- the use of architectural features like wing walls and parapets to create positive and negative areas to induce cross ventilation
- openings easily accessible and operable by the occupants
- equal inlet and outlet areas to maximise airflow
- the use good site planning, landscaping and planting strategies to cool incoming air

Stack Ventilation

Ventilation or stack effect is the movement of air into and out of buildings or chimneys, and is driven by buoyancy. When air movement is due to temperature difference between the indoor and outdoor, the flow of air is in the vertical direction and is along the path of least resistance. The temperature difference causes density differentials, and therefore pressure differences that drive the air to move.

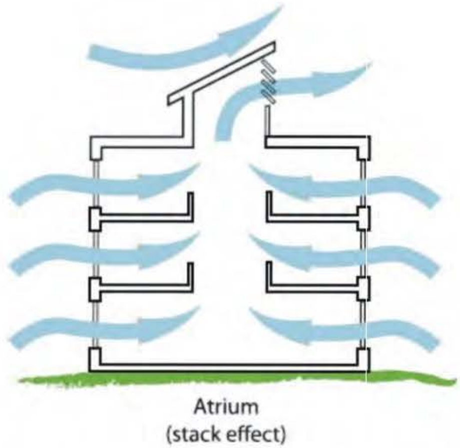


Figure 22: The stack effect is also referred to as the "chimney effect", and it helps drive natural ventilation.
Source: IEN Consultant

Some strategies include:

- provide at least two ventilation openings, one closer to the floor (inlet) and the other, higher in the space (outlet)
- maximising the vertical distance between these two sets of openings, as increasing the differential height will produce better airflow
- use louvres on inlets to channel air intake
- utilising architectural features like solar chimneys to effectively exhaust the hot indoor air

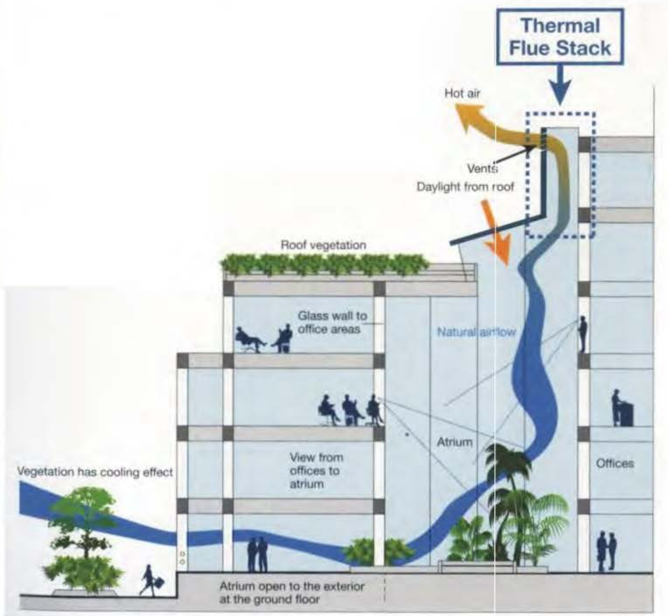


Figure 23: An atrium allows good ventilation as well as greater penetration of daylight
Source: Low Energy Office, Kementerian Tenaga, Air & Komunikasi (2004)

2.6 Infiltration

Infiltration is the unintentional or accidental introduction of outside air into a building, typically through cracks in the building envelope and through use of doors for passage. Infiltration is sometimes called air leakage.

Infiltration is caused by wind building pressurization and by air buoyancy forces known commonly as the stack effect. Infiltration of outside air into building brings moisture and requires a great deal of energy to be removed.

An ideal strategy in planning spaces according to different types of cooling may be referred to as the concentric ring (Figure 23). The 8-hours air-conditioned space and the spillover air-conditioned space may act as a buffer between the 24-hours air-conditioned space and non air-conditoned space.

This will help in controlling vast temperature difference and also condensation. Typically, infiltration is minimised to reduce dust, to increase thermal comfort and to decrease energy consumption. For all buildings, infiltration can be reduced by:

- sealing cracks in a building's envelope zoning of air-conditioned and non air-conditioned rooms

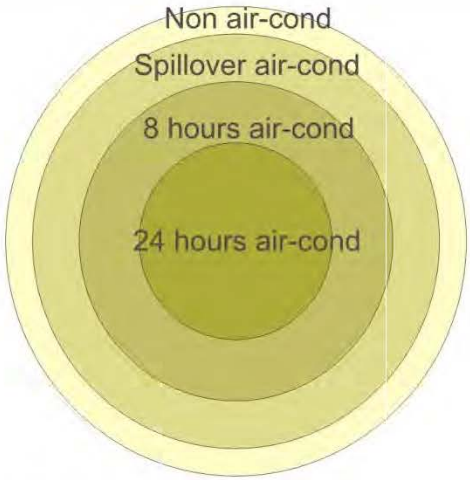


Figure 24: Concentric ring
Source: Cawangan Alam Sekitar & Kecekapan Tenaga, JKR

- ensuring all air-conditioned areas are air-tight through keeping windows and doors sealed when closed ~ door closers, rubber gaskets, door sweeps
- installing double door, revolving door or vestibules between air-conditioned and non air-conditioned rooms
- checking for “free returns” above the ceiling and avoiding these if possible
- make sure air-conditioned areas and non air-conditioned areas and non air-conditioned areas are properly separated

2.7 Building Envelope

The basic function of the envelope or enclosure of a building or structure is to protect the covered or otherwise conditioned interior spaces from the surrounding environment. Building envelope components have two characteristics that influence their performance:

- U-value & thermal resistance (R-Value)
  - The U-value is the measure of energy in Watts conducted through $1m^2$ of surface due to 1°C temperature difference between the surfaces
  - $U = 1/R$
  - Therefore, a **lower U-value** and **higher R-value** would provide better insulation for the building

- Exterior surface condition
  - light-coloured materials have low solar absorption and reflect heat
  - dark-coloured materials absorb heat

Figure 25: The controls on OTTV aim at reducing external heat gains through the building envelope and the electricity required for air-conditioning.
Source: Cawangan Arkitek, JKR

Wall & Roof Material

Green or environmentally-friendly material can help create more sustainable, healthy and environmentally-friendly building. The correct choice of building materials for façade design can help minimise solar heat gain. Green building materials offer specific benefits to the building owner and building occupants:

- reduced maintenance/replacement costs over the life of the building's energy conservation
- improved occupant health and productivity
- lower costs associated with changing space configurations
- greater design flexibility

When there is solar heat gain through building envelope in an air-conditioned building, it causes a higher cooling load and in a non air-conditioned building, thermal discomfort will occur.

In order to control this, Overall Thermal Transfer Value (OTTV) may be calculated to determine the design and materials to be specified. Careful selection (based on its properties) of materials is very important.

When the building is complete, sustainable facility maintenance practices will help to ensure the improved performance of green building materials and ultimately results in an environment friendly building.

Figure 26: Roof insulation is one of the most important design decisions for energy efficinet buildings because the roof plane receives the most solar radiation and for the longest period through the day
Source: Cawangan Arkitek, JKR

In addition, integrating green building materials into building projects may help reduce the environmental impact associated with the extraction, transport, processing, fabrication, installation, reuse, recycling and disposal of these building industry source materials.

It is important to choose the right wall and roof material. Below are factors that should be considered:

- solar heat gain through a building envelope in an air-conditioned building will result in higher air-conditioning cooling load
- solar heat gain in a non air-conditioned building will result in thermal discomfort
- according to MS 1525, buildings with an air-conditioned floor area of more than $4000m^2$, overall thermal transfer value (OTTV) should not exceed 50w/m, and the roof thermal transfer value (RTTV) should not exceed $25w/m^2$
- the OTTV may be calculated using computer software available or manually
- the careful selection of materials is very important

Figure 27: Mineral wool insulation.
Source: http://www.tradenote.net

Figure 28: Polystyrene insulation foam.
Source: http://www.kozyair.com/expanding-foam-insulation.jpg

Figure 29: Typical roof construction in Malaysia
Source: Kementerian Tenaga, Air & Komunikasi

wall composition	
description	**U-value (W/m2K)**
typical brickwall (115mm)	2.43
aerated light weight concrete (150mm)	0.86
thermal wall wt 100mm rockwool	0.37
single glazing	5.8
double glazing	1.2

Figure 30: U-values of typical types of building materials
Source: Kementerian Tenaga, Air & Komunikasi

2.8 Glazing

Glass has been used for thousands of years to allow daylight into our buildings. New windows, curtain walls and skylights for building construction should be selected on the basis of insulating glazing material for energy efficiency and comfort. The ideal glazing system would have :

- **Low Solar Heat Gain Coefficient, SHGC** (shading coefficient x 0.87, SC) ~ between 0 - 1
  - glazing's effectiveness in blocking heat caused by sunlight
- **Low solar transmittance** ~ < 65%
  - percentage of solar energy transmitted through glazing
- **Low U-value**
  - measure of energy conducted through glazing
- **High light transmission** ~ 70% 80%
  - percentage of natural light transmitted through the glazing

types of glazing available

- **tinted glazing**
  - lowered visual and light transmission
  - improved versions offer better visible transmission and a good shading coefficient
  - if utilised, the glazing area needs to be increased according to ratio of the daylight transmission

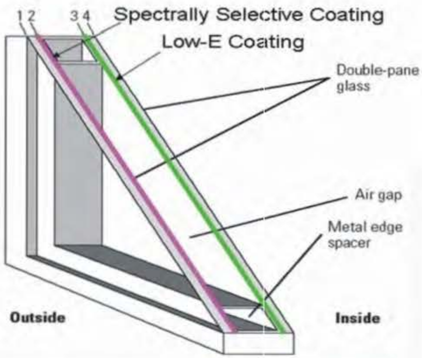
- **coated glazing**
  - spectrally selective greater light transmission and lower solar transmission
  - low-e allow visible light and lower solar transmission by absorbing and not radiating the heat

- **filmed glazing**
  - thin film applied in between or on the inside surface to improve performance of glazing

- **double glazing**
  - better insulation from heat transfer
  - space filled with *inert gas**, i.e. argon or krypton
  - coating/film may be applied on the inner surface preventing damage

** **an inert gas** is a non-reactive gas used during chemical synthesis, chemical analysis, or preservation of reactive materials.*

Figure 31: Double glazing windows are formed by placing two panes of glass several millimeters apart, creates a pocket between the panes that traps air and forms a highly efficient insulating layer in windows and doors.
Source: http://www.brightoncarpentry.co.uk



glass type	heat %	light %	U-value W/m2k
single	85	85	6
double, spectrally selective, gas filled	25	50	1

Figure 32: Typical double glazing
Source: IEN Consultant

2.9 Daylighting

Daylighting is the controlled admission of natural light into a space through windows to reduce or eliminate electric lighting. Natural light helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs.

To maximise daylighting potential, a shallow floor plate is preferred. Inner courtyards and atriums can bring light into central cores, especially in low building. Daylight penetration into a space can be increased by using light shelves. This is a horizontal elements with a high-reflectance upper surface that reflects light onto the ceiling and deeper into space.

Designers must be careful to avoid glare and overheating when placing windows. More windows do not automatically result in more daylighting. That is, natural light has to be controlled and distributed properly throughout the workspace.

Skylights and light tubes can provide daylight through roof to the spaces below. Skylights often also allow heat gain and can be a potential source of glare. Diffusing glazing can help to alleviate this problem. Light tubes collect light through an exterior transparent dome and bring it to the interior through a reflecting metal pipes and a diffuser at the ceiling level of the .space

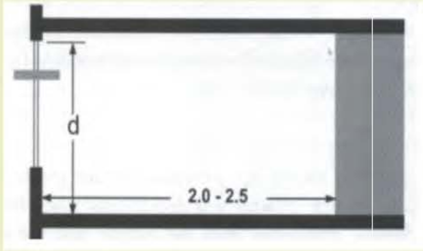
Figure 33 & 34: The use of daylight tube to reduce the need for artificial lighting

Using daylight not only makes people happy and more productive, it is a "free" source of light and produces less heat for a given illuminance than electric lighting. Direct sunlight admittance must be avoided.

When there is glare and overheating, users will always try to totally block out natural lighting and resort to artificial lighting. Light shelves are used on the north/south-facing windows. External overhangs shade the windows and effectively reduce cooling loads.

- a rule of thumb for daylight penetration with typical depth and ceiling height is **2.0-2.5 times head height**
- rooflights and light tubes should be used to bring daylight deeper into the building
- **do not** allow the entry of direct sunlight, but only diffused light ~ it is cooler and has less glare
- a light shelf will improve daylight penetration

Figure 35 & 36: Diffuse daylight with an efficiency of around 120 lumen/watts is twice as good as traditional fluorescent lighting, which provides around 60 lumen /watts
Source: IEN Consultant



A rule of thumb for daylight penetration with typical depth and ceiling heights is 2.0 - 2.5 times head height. A light shelf will improves daylight penetration.

Figure 37: Daylight Fenestration
Source: Kementerian Tenaga, Air & Komunikasi (2004)

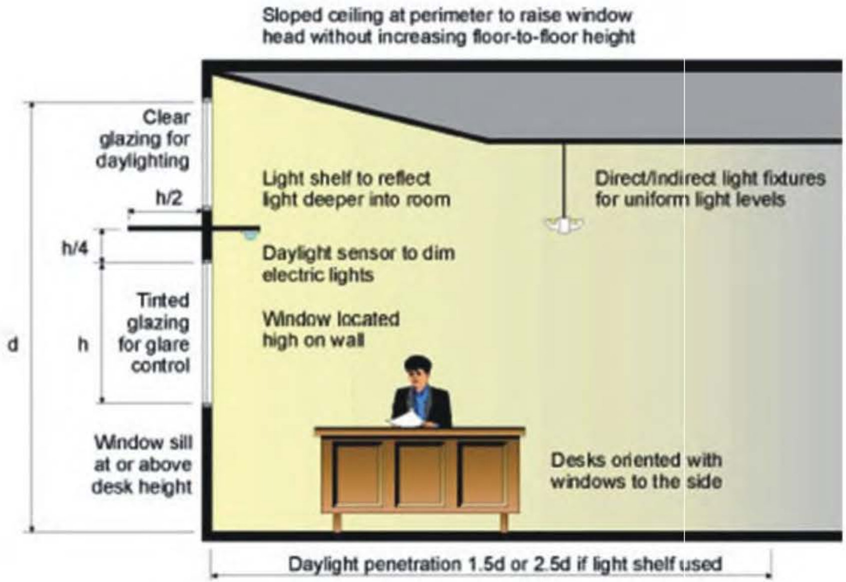


Figure 38: Optimizing Daylight Fenestration
Source: Kementerian Tenaga, Air & Komunikasi (2004)

Figure 39 & 40: A light shelf between the upper window and lower window would helps to further distribute daylight to the back of the room by bouncing lights off the shelves to bring illumination deeper into the room
Source: http://www.lotuslive.org/ & http://www.agsinc.org/lightshelves

2.10 Sunshading

There are many reasons to control the amount of sunlight that is admitted into a building. In hot, sunny climates excess solar gain may result in high cooling energy consumption. Shading can be provided by:

- natural/strategic landscaping
- building elements such as awnings, overhangs or trellises
- the building form itself, e.g orientation
- design of façade and openings, e.g punch hole windows

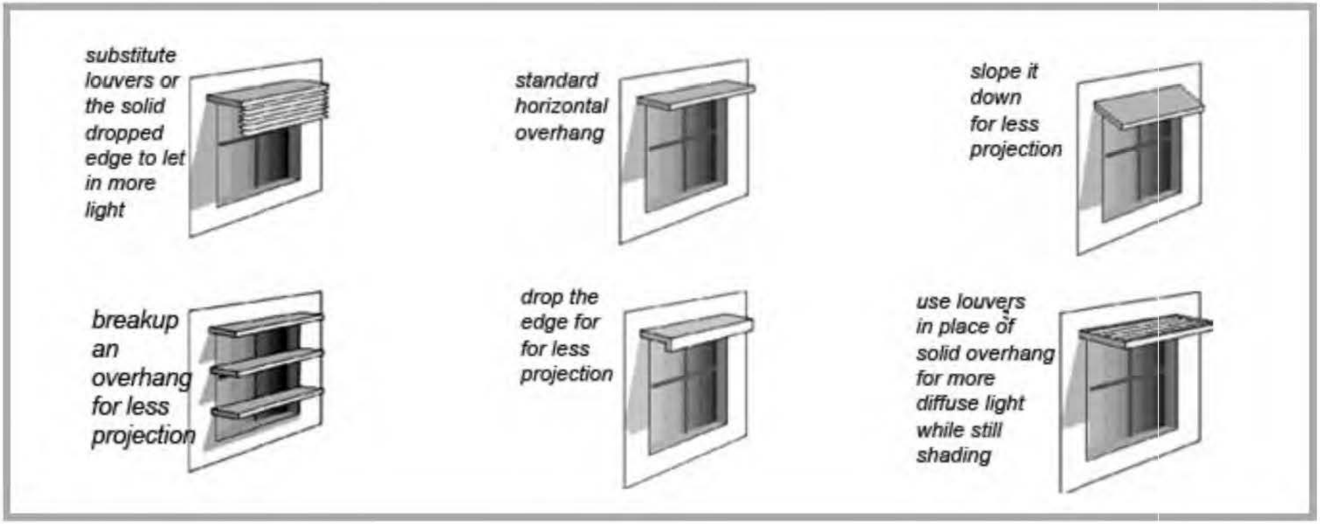


Figure 41: Options of horizontal shading
Source: Low Energy Office, kementerian Tenaga, Air & Komunikasi (2004)

Exterior shading systems are more effective than interior systems in blocking solar heat gain into the building. Design of sunshading devices may vary as long as these criterias are met:

	north / south / west / northwest / southwest	east / northeast / southeast
horizontal shading length	0.35 x height of window	0.7 x height of window
vertical shading on both sides of window	at least 350mm width on both sides	

Figure 42: Criterias of shading device

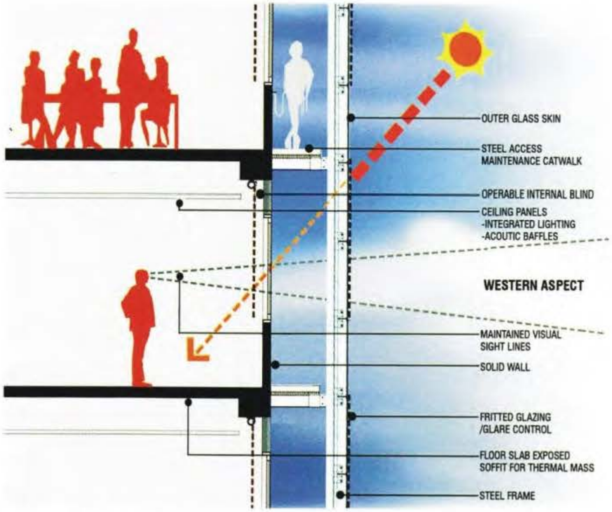


Figure 43: Double skin concept
Source: Futurarc, 1st Quarter 2010, Volume16

Figure 44 & 45 : The objectives of shading devices is to prevent direct sunlight from entering building through the glazing.
Source: Cawangan Arkitek, JKR

3.0 Active Design for Energy Efficiency

When designing an energy-efficient building, the active part of the building needs serious consideration although the cost implication would be greater, unlike passive design strategies. However, it is worthwhile to look into these considerations and discussed with the appropriate designers :

- **energy efficient chillers**
  - coefficient of performance (cop) of chillers
- **energy-efficient light fittings**
  - lighting load
    - use energy-efficient lights and ballast
  - light zoning
    - occupancy/daylight sensor
    - light switch next to exit door
    - lighting zones parallel to windows
  - all lighting controls should be located at an accessible place with the following acceptions:
    - automatic controls
    - programmable controls
    - controls requiring trained operators
    - control for hazards and security

Figure 46 & 47: Energy efficient lighting fittings

- **energy-efficient office equipments such as :**
  - laptops
  - sharing of network printer
- **air tightness of air-conditioned spaces**
  - use CO_2 sensors to regulate fresh air intake ~ CO_2 limit <1000ppm
- **integrated building design ~**
  - use available simulation softwares for simulation e.g IES, Ecotect, Energy 10
- **energy management system**
  - to be designed as part of the building control system
  - able to monitor :
    - electrical load performance
    - air-conditioning performance
    - overall energy performance
- **building integrated photovoltaics (BIPV)**
  - the integration of photovoltaics (PV) into the building envelope
  - PV modules serve the dual function of building skin - replacing conventional building envelope material - and power generator
  - BIPV systems are interfaced with the available utility grid, may also be used in stand-alone, off-grid systems

Figure 48, 49, 50: Proposed BIPV location at Perdana Putra, Putrajaya
Source: Cawangan Arkitek, JKR

4.0 Conclusion

For more than 100 years, the Public Works Department (PWD) has touched many aspects of the nation's life.This department provides infrastructure and a conducive environment for living, working, playing and learning. By implementing Energy Efficiency (EE) in government buildings through the JKR Strategic Framework (2007-2010), it will increase awareness among designers in order to achieve a sustainable living environment. It also aims at reducing the cost of running for a building as it will reduce the energy consumption. This is our responsible which needs to be adopted by all for a better tomorrow which created a need to go green in every sphere of life, including architecture and built environment.

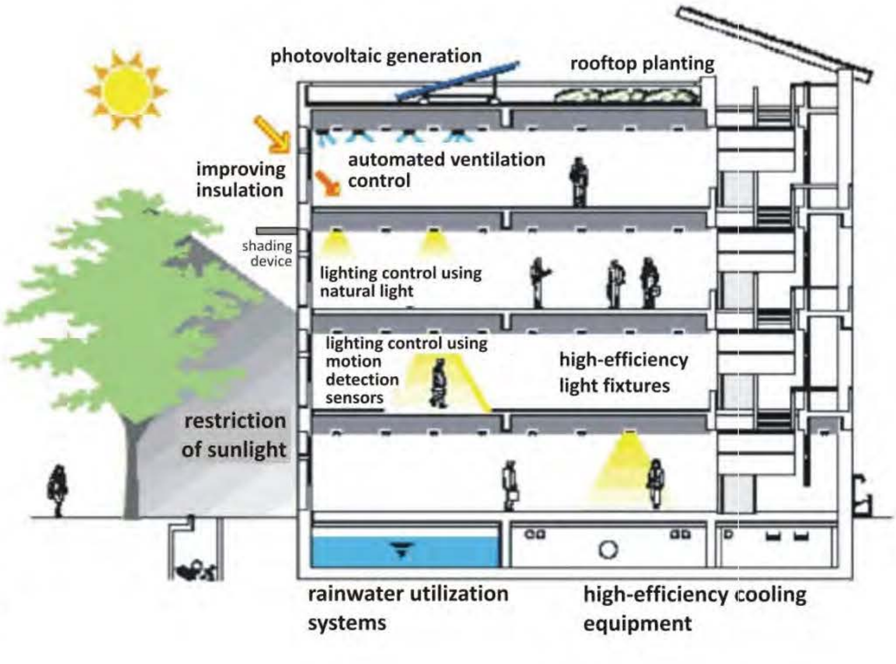


Figure 51: Conceptual Drawing of Green Building
Source: http://www.newenglandmetalroof.com

5.0 Appendix

checklist of passive design strategies for an energy efficient building

	item	key points	√ / X
1	building orentation	main facades facing north/south	
		east/west facades ~ incorporate shading means and devices	
		east/west facades ~ extra insulation or landscaping	
		building form contributes to the shading of adjacent open spaces	
		analyse microclimate information	
2	façade design	high thermal performance	
		wall and fenestration system provide view	
		wall system and fenestration must provide daylight and glare control	
		wall system and fenestration must provide aesthetics ~ building image	
		wall system and fenestration must provide maintainability	
		a building facade system should have a high thermal performance	
3	strategic landscapes	shading of direct exposure to east/west facing facades	
		creation of cooler microclimate around the building	
		evaluate existing soil and plants on site	
		identify existing mature trees and plan accordingly to minimise felling	
		maximise softscape and keep it permeable	
		landscape at least 20% of the total site area	
		green roofs and green walls to be used	
		choose appropriate high albedo materials (high reflective and high emissivity paving or roofing materials) to reduce heat gain	
		incorporate aquascape (if possible)	
		keep hard and surfaces away from building	
		use green roof as rainwater detention or retention	
		use green roof to increase the thermal resistance and capacitance of a roof assembly	
		use green roof to provide habitat for animals or an amenity for people	

	item	key points	√ / X
4	space planning	● locating spaces in their ideal thermal location	
		● no intense planning	
		● smaller courtyards	
		● more open concept offices/areas nearer to the façade	
		● effective room depth fingerlike designs	
		● transparent/high light transmittance internal partitions	
		● light coloured walls and ceiling	
		● effective floor to ceiling height	
5	natural ventilation	● consider natural ventilation ~ cross/stack in areas : ○lobby areas ○corridors ○lift cores ○staircases	
		● building form maximises exposure to the prevailing wind direction	
		● minimise internal obstructions (between inlet and outlet)	
		● use architectural features like wing walls and parapets to create positive and negative areas to induce cross ventilation	
		● make openings easily accessible and operable by occupants	
		● have equal inlet and outlet areas to maximise airflow	
		● use good site planning, landscaping and planting	
		● create stack ventilation by providing 2 ventilation openings, one closer to the floor (inlet) and the other higher in the space (outlet)	
		● maximise the vertical distance between these two sets of openings for stack effect	
		● use stack wells (continuous vertical elements) to ventilate adjacent spaces	
		● use architectural features like solar chimneys to effectively exhaust the hot indoor air	
6	infiltration	● seal all cracks in a building envelope	
		● zoning of air-conditioned and non air-conditioned rooms	
		● air conditioned areas must be air-tight	
		● windows and doors sealed when closed ~ door closers, rubber gaskets, door sweeps	
		● consider double door, revolving door or vestibules between air-conditioned and non ● air-conditioned rooms	
		● check on "free returns" above the ceiling.	

	item	key points	√ / X
7	building material	● choose correct building materials to minimise solar heat gain	
		● choose sustainable materials: ○low toxicity ○minimal emissions ○low VOC (volatile organic compounds) assembly ○recycled content ○recyclable materials ○reusable	
		● use low u-value materials for building envelope	
		● use light-coloured material for external surface	
		● use glazing with low SHGC (solar heat gain coefficient) ~ between 0 - 1	
		● use glazing with low solar transmittance < 65%	
		● use glazing with low u-value	
		● use glazing with high light transmission ~ 70% - 80%	
8	daylighting	● calculate daylight penetration by rule of thumb	
		● avoid glare and overheating by using diffused light only	
		● use lightshelves to improve daylight penetration	
		● lightshelves to be used on the south/north facing windows	
		● use sunshading to avoid direct sunlight	
		● use rooflights and light tubes to bring in daylight further in	
9	sunshading	● use natural / strategic landscaping for sunshading	
		● use building elements such as awnings, overhangs or trellises for sunshading	
		● the building form itself can be a sunshading	
		● design façade and openings so as to act as sunshading	

6.0 References

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