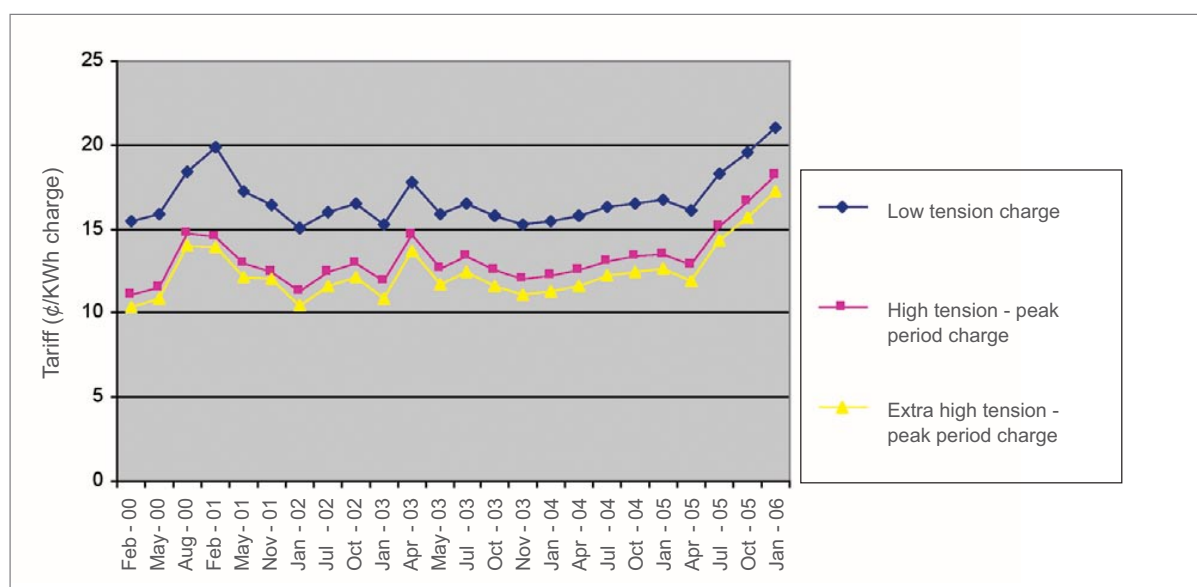


2. ENERGY EFFICIENCY

According to a study conducted in the United States, although the average premium for green buildings is about 2% more than conventional buildings, they are 28% more energy efficient [1]. It is also noted that if green building features are incorporated during the earlier design stage, the cost will be much lower.

As Singapore is a city-state with limited natural resources, it is important for our buildings to be energy efficient. According to a report from National Climate Change Strategy, energy use in buildings made up 16% of Singapore's energy demand in 2004 [2]. It is noted that air-conditioning forms a large part of energy consumption due to Singapore's tropical climate.

The graph below shows the electricity tariff from Feb 2000 till Jan 2006. The electricity tariff is reviewed quarterly and it will be adjusted according with the fluctuation of oil price. This is due to the fact that fuel cost makes up about 50% of the cost of electricity. The recent few quarters' sharp increases in fuel oil have caused the electricity cost to increase sharply. It has become more important for a building to be energy efficient.



Source : Singapore Power

2.1. BUILDING ENVELOPE DESIGN

2.1.1. BUILDING ENVELOPE

The architecture of a building has a very significant impact on its energy efficiency. Energy efficiency should be considered when the building is in the conceptual stage of architecture design. The Envelope Thermal Transfer Value (ETTV) is key to better energy efficiency in air-conditioned buildings.

Heat absorbed from the environment (especially solar heat) by the walls, windows and roof of a building makes up a large portion of a building's cooling needs. Hence, it is important to minimize this heat gain when designing the architecture.

Air-conditioned commercial buildings should be designed to have a low ETTV. The "Guidelines on Envelope Thermal Transfer Value for Buildings" issued by the Commissioner of Building Control states that the ETTV of air-conditioning building shall not exceed 50W/m². The detailed information on ETTV can be obtained from BCA website, www.bca.gov.sg

As the lower the ETTV of a building envelope, the less energy is required to cool the building, points will be awarded to buildings applying for Green Mark Scheme based on their ETTV (refer to draft of revised Green Mark assessment criteria in Appendix A).

Republic Polytechnic with EETV of below 45 W/m²



Republic Polytechnic Centre



The Republic Cultural Centre

Currently, there is a software design tool named Building Energy Standards (BEST) which can be used to calculate ETTV, heat loads and energy consumption of air-conditioned buildings. BEST was developed by National University of Singapore (NUS) in collaboration with BCA.

2.1.2. ENERGY EFFICIENCY INDEX

The designer is encouraged to use the Energy Efficiency Index (EEI) to gauge the energy consumption in buildings. To enhance the energy performance, it is important to have detailed energy performance data and indicators. The estimated energy efficiency index of building can be calculated using the BEST software mentioned earlier.

A study conducted by the Centre for Total Building Performance (CTBP), a joint venture of the National University of Singapore (NUS) and BCA had collected energy consumption data for 104 office buildings in Singapore. The study shows that the energy performance of a building can be assessed using an energy efficiency index regardless of a building's size, height or age.

According to the study conducted on Energy Efficiency of Office Buildings in Singapore [3], only the top 10% of the office buildings have EEI of 150KWh/m²/yr and below.

Some Previous EEBA* Winners with EEI below 150 KWh /m² /yr



Capital Tower



Nanyang Polytechnic

* **EEBA**– BCA's Energy Efficient Building Award. With the introduction of Green Mark, this award was discontinued from 2006.

2. ENERGY EFFICIENCY

A scheme jointly developed by the National Environment Agency (NEA) and NUS – the Energy Smart Building Scheme provides recognition to building in the top 25% of their class for achieving exemplary energy efficiency without compromising the indoor environmental quality.

BENEFIT

This EEI data would allow building managers and architects to benchmark the energy efficiency of their buildings and also allow them to set targets for their energy performances.

2.1.3. BUILDING ORIENTATION

Building orientation has a significant impact on the building's ability to reduce cooling load, the extent of natural ventilation and utilization of daylighting. Some good examples are shown below.

Design long facades with windows facing north-south orientation



Minimize surface areas and windows on east & west facades



Design non-air conditioning areas (e.g. staircases, corridors, service core, etc) along building sides facing east and west as buffer to the air-conditioning areas



Design windows on west facades with low emissivity (low-e) coatings to reduce solar heat gain



POINTS TO NOTE

- Heat gained from solar radiation by east/west facades is much higher than north/south facades.
- To avoid excessive solar heat gain and glare, the practical range of glazing area should be 20% to 40%. If sufficient external sun-shading is provided, this could be increased to 50%.

2.1.4 SUN-SHADING

Sun-shading should be intelligently designed by taking into consideration its function as a shading device for thermal comfort. It should also retain its aesthetic value while allowing enough daylight to the rooms. Sun-shading should be provided for facades facing east and west to partially shade the building from direct sunlight to minimize solar heat gain. Some good examples of sun-shading are shown below.

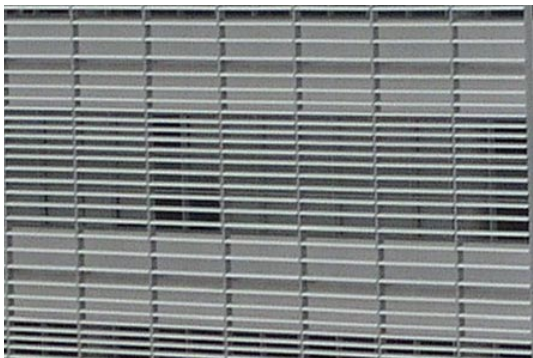
Effectively designed sun-shading



Design units with balconies and/or planters and bay-windows that act as sun-shades



Trellises with specially designed shading profile



Windows with large overhangs



To minimize solar heat gain, inter-block shading can be considered where applicable. This allows facades with sun shading to use less expensive glass and day lighting

POINTS TO NOTE

- When designing shading devices for east and west facades, it is important to take into consideration the low sun angles which are harder to shade.
- When selecting colour of shading system, it is important to note that light colours are better at reflecting solar radiation.

2. ENERGY EFFICIENCY

2.1.5 FACADE MATERIALS

Facade materials should be carefully selected to ensure energy efficiency of the building. Some examples of reducing solar heat gain by designing appropriate glazing and insulation of building envelope are as follows:

Design glazing with low emissivity (low-e) coatings



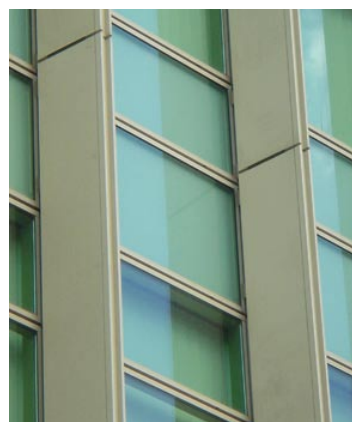
Insulating roof such as second layer roof system or roof top garden



Design light colours building facades and reflective roof surface to avoid excessive heat absorption



Using cavity walls, double glazed windows/curtain wall glass etc to increase the envelope's insulating properties



POINTS TO NOTE

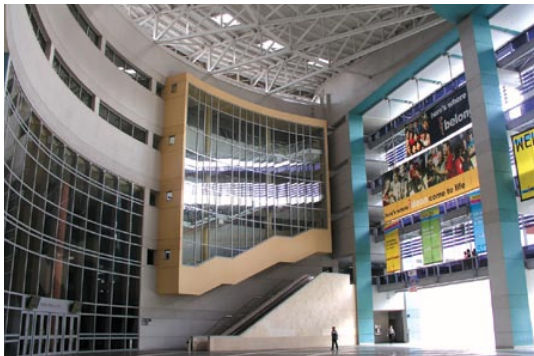
- Using glazing with low-e coating allows high transmission of light without excessive heat gain. It reduces solar heat gain without compromising on the level of daylight entering the building.
- It is advisable to use glazing that allows approximately 50% of visible light transmission to ensure a good balance between artificial lighting and natural lighting.
- According to information provided by Efficient Window Collaborative (EWC)*, a typical house using windows with double low-e glazing can achieve a saving of up to 32% cooling energy cost compared with a house using clear single glazing. Details of the benefits can be found at website, www.efficientwindows.org

**EWC was formed by the Department of Energy and key players in the U.S. window industry to ensure that efficient windows reach their optimum potential in homes throughout the U.S.*

2.2. DAY LIGHTING

Wherever possible, day lighting should be incorporated into the building as the preferred mode of interior illumination. It provides the highest quality light with significant health benefits and feeling of well-being. It also reduces lighting load and operation costs. Some examples below highlight the uses of day lighting.

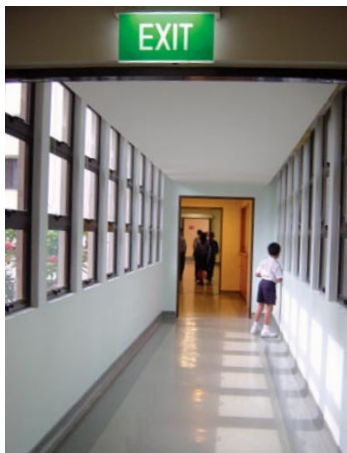
Incorporate skylight at atrium or open courtyard to bring daylight into the interior



Design office space by allowing transmission of diffused day lighting in office perimeter.



Design open corridors and staircases along perimeters of building to make use of day lighting



To save energy, place photocell-dimming sensors at the main lobby, auditorium, perimeter of office, sky lobby areas etc to detect daylight and activate the dimmer to reduce the lighting level in response to the amount of available natural light



POINTS TO NOTE

- When using day lighting, care should be taken not to introduce too much solar heat gain into the space. Sun-shading devices should be provided to minimize heat gain and also to exclude undesired glare. The choice of glaze is also critical in ensuring good day lighting.
- When incorporating day lighting, it is important to design a system that minimizes contrast ratios and integrate natural and electric lighting. Lighting design should not only consider energy consumption but occupant satisfaction and productivity.
- To have good quality lighting, daylight sensors should be located in a manner such that the portion of the lighting zone being controlled experiences fairly uniform illumination levels.

2. ENERGY EFFICIENCY

2.3. NATURAL VENTILATION

Natural ventilation should be designed wherever possible to minimize the cooling load required and save energy. Some examples below highlight areas suitable for natural ventilation such as lobbies, courtyard, car park, etc., where requirements of comfort level are not so crucial as to affect occupant's satisfaction and productivity adversely.

Design open courtyard to enable lobby to be naturally ventilated



Design natural ventilation for covered link-ways or link-bridges through cross ventilation openings



Where applicable, use natural ventilation or partial natural ventilation for car park areas



Design natural ventilation or partial natural ventilation for transition spaces or spaces with short interval usage such as canteen



For some of the areas with large variations of occupants such as multipurpose or sport hall, hybrid ventilation i.e. combination of natural and mechanical ventilation modes could be considered to save energy. For example, most of the time, natural ventilation can be used to conserve energy and mechanical ventilation can be activated only when the occupancy rate is high.

POINTS TO NOTE

- To ensure occupants' comfort, the design of natural ventilation should be carefully analyzed.
- For more complex cases, it is advisable to carry out airflow and energy simulations, using the wind and meteorological data. The effects of surrounding obstructions such as block spacing and arrangement should be taken into consideration.

2.4 AIR-CONDITIONING SYSTEM

In Singapore's tropical climate, 52% of electricity consumed in buildings goes towards air-conditioning and refrigeration [4].

Although the majority of air-conditioning power is being consumed at the chiller or air-con compressor, other components like distribution pumps and fans should not be neglected. When examining air-conditioning system efficiency, a whole system approach should be considered instead of addressing each component of the system individually.

Software tools are available to help a designer analyze the building air-conditioning requirement. The cooling load pattern and profile of the building should be analyzed and developed so that suitable combination of equipment can be selected to achieve optimum system efficiency at all times.

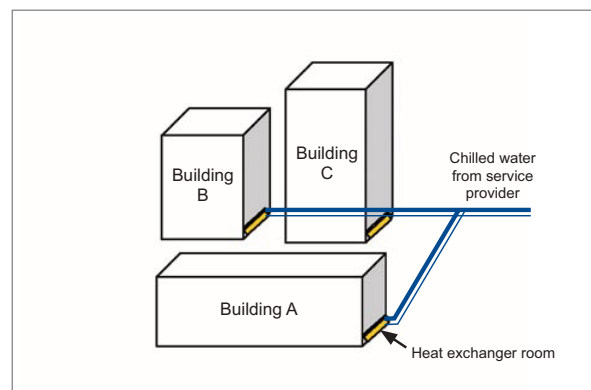
2.4.1 DISTRICT COOLING

District cooling provides cooling needs to several buildings on the same site. A centralized chilled water plant can provide the cooling requirements of these buildings more effectively.

District cooling are suitable for projects with several buildings in close proximity. In Singapore, district cooling are available at some business development areas such as Changi Business Park and Biopolis.



Centralised chiller system



District Cooling System by service provider

BENEFITS

- Produce chilled water more efficiently
- For building subscribing to district cooling system with service provider:
 - o Savings in up-front capital investment
 - o Savings in maintenance and operating costs
 - o Saves space as no chiller room and cooling tower space required
 - o Design flexibility to meet future cooling load demand

2.4.2 CHILLER EFFICIENCY

Select appropriate number and size of chillers according to the cooling load profile of a building to ensure that the chiller systems are always running at their optimum system efficiency at all times. Appropriate sizing is critical to achieving energy efficiency. Many existing systems are oversized. An oversized chiller not only cost more to purchase, it also costs more to operate.

2. ENERGY EFFICIENCY

While the chiller must be sized for peak load, it is also important to be sure that it operates efficiently at part load conditions because it is at part load that the chiller operates most of the time. Table 1 shows the water cooled chiller types and their recommended full load efficiencies:


Centrifugal water-cooled chiller	Table 1 : Water-cooled chiller types and recommended efficiencies	
	Chiller Type	Full-load efficiency*(KW/ton)
	Centrifugal	0.56 or less
	Screw	0.64 or less
	Reciprocating	0.92 or less
*Full load efficiency is measured at peak load conditions as described in ARI Standards 550/590-1998		

POINTS TO NOTE

- Currently, most of the air-conditioned buildings use multiple chillers. It is important to note that the individual chiller load profile bears little resemblance to a multiple chiller system load profile. Multiple chiller system design requires proper system configuration and a well thought out strategy to achieve optimum system operating efficiency.
- Chiller part load efficiency depends also on the cooling tower water temperature (for water cooled system) and ambient air temperature (for air-cooled system). It is therefore important to establish a realistic condenser temperature in tropical climate even when comparing part load efficiency, in order to have a more realistic energy simulation. Sizing and siting of cooling towers and air-cooled condensers have important effects on cooling plant efficiency.


2.4.3 VSIDS ON CHILLED WATER PUMPS

Use variable speed drives (VSDs) to ensure that chilled water pumps are performing at maximum efficiency at part-load conditions. Use VSDs to maximize energy saving at building part load conditions. Varying the speed of pumps allow the efficient circulation of chilled water at building part load.

VSDs on chilled water pumps	Potential saving
	<p>VSDs save energy for electric motors driving pumps when capacity is reduced. It must be noted that the power consumption of motor varies approximately with the cube of the motor speed. This means that a reduction of speed by 20% will result in reduction of power consumption by a half i.e. 50% saving. Since most air-conditioning system seldom runs at full load, significant energy saving can be made with these VSDs.</p> <p>An Energy Conservation Project at NTU [5] shows that by implementing VSD control on chilled water pumps, an average saving of 18% on chiller plant power was recorded.</p>

2.4.4 USE VAV SYSTEM WITH VSDS ON FANS

Use variable air volume (VAV) for air distribution to allow for better zone temperature control. Use VSDs to vary the speed of fans for VAV system to efficiently match the actual load required.

VAV system with VSD on Fan	Potential saving
 <p>VAV AHU</p>	<p>The fan and motor are initially designed and installed to meet the maximum cooling load of the room. During normal operation, the fan may operate at levels below its maximum rating. Varying the fan speed to satisfy the actual operating requirement will significantly reduce the energy consumed by the fan and motor. This savings can be as much as 15%.</p>



2.4.5 VARIABLE SPEED COOLING TOWER

Use cooling tower with variable speed fan to achieve closer match to the actual cooling load required.

The variable speed operation varies the airflow through the cooling tower in accordance to the load variation on the system. By varying the airflow through the cooling towers, it achieves a maximum total chiller plant efficiency based on building load and ambient wet bulb temperature variation. As the fan speed reduces to meet load requirements, the fan input power required will be substantially reduced.

2.4.6 ZONING

Design isolated zone with fan coil unit (FCU) or separate air-conditioning system to serve areas with different occupancies and needs. Some examples are as follows.

FCU	VRV
<ul style="list-style-type: none"> Use fan coil units (FCUs) to serve small areas that have irregular operation hours. VAV type single zone FCU can be considered. 	<ul style="list-style-type: none"> Use inverter-controlled variable refrigerant volume (VRV) packaged units for rooms that require 24-hours operation
	
BENEFIT	BENEFIT
<ul style="list-style-type: none"> FCU allows the individual small areas to operate independently on-demand. Energy consumption is also minimized as the FCUs serve discrete rooms. 	<ul style="list-style-type: none"> VRV packaged units avoid the need of operating cooling plants to support small load, especially after normal working hours, thereby saving energy. The use of inverter-controlled VRV packaged units also ensures load-capacity matching for energy savings.

2. ENERGY EFFICIENCY

2.4.7 MOTION SENSORS

Design air conditioning systems that automatically turn on and off by motion sensors in areas where usage are low and irregular such as at meeting rooms and gymnasiums.

2.4.8 CHILLER PLANT SYSTEM CONTROL

Design optimum sequencing of chillers, pumps and cooling towers to match the exact cooling load requirements to minimize chiller/pump/cooling tower running time.

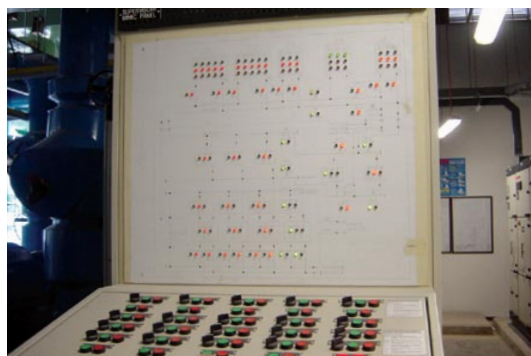
Sequencing control of multi-chiller plant is required because the air-conditioning system generally does not operate at full capacity all the time. Effective sequencing control operates optimum number of chillers to meet the varying load and hence save energy.

Control and monitoring facilities should be incorporated in the systems. Adequate monitoring and control enable regulation and tuning of air-conditioning systems to operate at optimum efficiencies with minimum energy consumption. The savings can be very significant. For example, by simply optimizing the operation of air-conditioning system, savings of up to 17% electricity consumption can be achieved.

Chiller sequencing



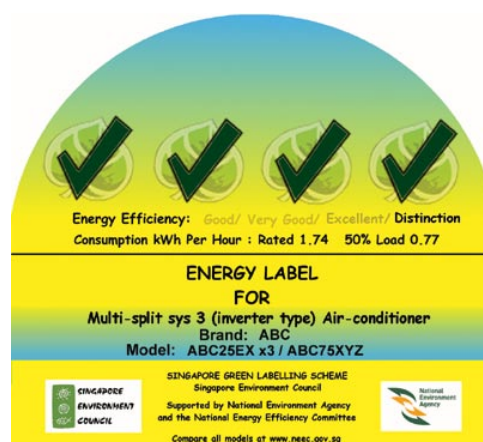
Control and monitoring facilities



2.4.9 Energy Labels

For split unit air-conditioners, use Singapore's Energy Labelling Scheme to select more energy efficient types.

Detailed information on energy efficiency of various models of air-conditioning products can be found at Singapore's Energy Labelling homepage www.nec.gov.sg/energylabel/



Logo of Singapore Energy Label

2.5 LIGHTING

Lighting consumes a relatively large amount of electricity. A reduction in lighting load reduces electricity used and also reduces heat gain in the space, which in turn results in reduction in air conditioning load.

Lighting design should not only consider energy consumption but occupant satisfaction and productivity. It is important to design a lighting system that minimizes contrast ratios. Where applicable, integrate natural and artificial light sources and employ advanced lighting controls.

Automatic controls can conserve energy but they should be designed to avoid annoying the occupants. Occupants should be advised about the performance and functions of the lighting control system. Use of local controls and manual overrides can facilitate users' acceptance of the system.

2.5.1 ENERGY EFFICIENT LAMPS

Energy efficient light fittings should be used with energy efficient lamps such as "T8" or "T5" fluorescent lamp.

Table 2 compares the luminous efficacy of lamp types commonly used. Lamp luminous efficacy is the ratio of the lumens emitted by the lamp to its power consumption (watts). The efficacy of the lamps in Table 2 is based on the lumens output when the lamp is new and the power taken by the lamp only. It includes the power taken by the ballast where the ballast is built into the lamp.


"T5" fluorescent lamp	Potential saving
	The use of T5 lamps combined with electronic high frequency ballast can save energy by up to 40% compare with equivalent standard TL-D systems.

Table 2: Comparison of luminous efficacy of common types of lamps

Lamp types	Lumens per Watt	Average life (operating hours)
Incandescent	12-15	1,000
Tungsten-halogen	15-25	2,000-5,000
Mercury vapor	30-50	24,000
Compact fluorescent	40-80	8,000-12,000
Tubular fluorescent	50-100	10,000-15,000
• fluorescent tube "T8"	90	12,000
• fluorescent tube "T5"	105	17,000
High pressure sodium	60-110	24,000
Low pressure sodium	70-180	18,000
LED	70	40,000


Source : (6), (7) & Phillips

This table is for reference only

2. ENERGY EFFICIENCY

2.5.2 HIGH FREQUENCY ELECTRONIC BALLAST

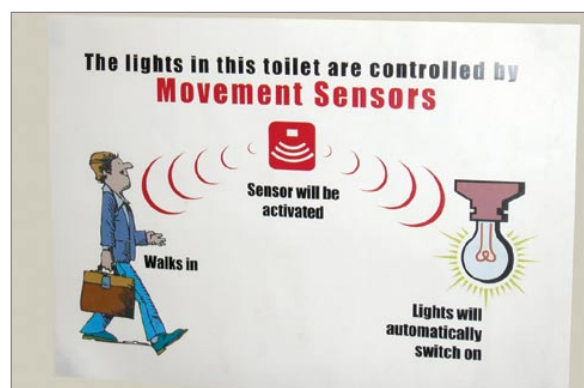
Install fluorescent light fittings with high frequency electronic ballasts for energy efficiency. Operating the fluorescent lamps at higher frequencies can significantly enhance the lumen watt of the lamp output as fluorescent lamps are sensitive to the operating frequency.

High frequency electronic ballast	Potential saving
	The efficacy of the lamp can be improved by about 10% when fluorescent lamps are operated at higher frequencies.

2.5.3 OCCUPANCY SENSORS

Use occupancy sensors such as motion sensors to detect occupant motion and light the space only when it is occupied for spaces that have highly variable and unpredictable occupancy patterns, such as staircases, toilets, gyms, etc.

Energy is wasted when lights are left on in unoccupied rooms for prolong periods.



POINT TO NOTE

- Energy savings may not be realized if the sensors are improperly installed or are disabled by dissatisfied occupants. It is important to ensure that the sensor installation is properly selected, positioned and tested. It must be able to "see" the range of motion in the entire space to avoid switching off of lights when the space is occupied with little activity.

2.5.4 SCHEDULING

For spaces where lighting needs are predictable and predetermined, use automatic scheduling controls to switch on and/or off the lights for energy savings.

POINTS TO NOTE

- Some localized override controls should be provided for locations where lighting is needed beyond the scheduled period. This will prevent unnecessarily illuminating the entire area.
- Some local overrides (on zone basis) can be provided via:
 - o Wall switches
 - o Calling the Building Management System (BMS) centre
 - o Interactive voice response
- Local warning should be provided so that occupants will not be "caught in the dark"



2.5.5 USE OF DIMMERS

Lighting in an area can be dimmed if all employees have common lunch hours.

Design a sensor that measures the lighting level in a space to allow a dimmer to adjust the light output to the required lighting level. This will save energy by reducing lighting to the required lux level. This will be useful for new buildings as lamps provide higher light output at the start of their life when the initial lux level will normally exceed design specifications.

2.5.6 ZONING

Multiple wiring circuits should be used to facilitate variation of lighting level. Some examples of zoning for special usage are highlighted below.

<ul style="list-style-type: none"><i>To take advantage of natural lighting, lighting in corridors, passageways and rooms located close to window areas should be installed in multiple circuits</i> 	<ul style="list-style-type: none"><i>Exterior lighting should be controlled by photocells where possible</i> 
BENEFIT	BENEFIT
<ul style="list-style-type: none">This allows partial lighting during daytime and/or after hours at night.	<ul style="list-style-type: none">Conventional external lighting depends on timer and it will become difficult to control the timing during different time of the year. The use of photocell will save energy and it is no longer be necessary to manually turn on or off the light.

POINTS TO NOTE

- When planning for automatic lighting control, it is important to ensure that certain potentially dangerous places such as staircases can not be inadvertently plunged into total darkness.
- All individual or enclosed spaces should have individual switches. The switches should be clearly labeled and easily accessible by building occupants. This makes it easier to light only occupied areas.
- If employees or divisions that frequently work overtime can be identified in the early stage of office layout design, they can be grouped in the same areas. This will limit the areas of night time operation of the lighting system.

2. ENERGY EFFICIENCY

2.6 LIFTS AND ESCALATORS

2.6.1 EFFICIENT LIFTS

Design traction lift with AC variable voltage and variable frequency (VVVF) motor drive for energy efficiency. It is highly recommended that even for lifts with speed under 1m/s, AC VVVF should always be considered whenever feasible.

Use AC synchronous motor, preferably with permanent magnets to avoid the problem of poor power factor in AC asynchronous motor. Furthermore, torque pulsation is a problem for AC asynchronous motor when operating at low frequency and low speed range.

Design motor drive system with either gearless type or planetary gear type. The elimination of gear improves the energy efficiency as gearless drive has no gear transmission loss.

Energy efficient features	Potential saving
<ul style="list-style-type: none"> Lift with AC VVVF motor drive 	<p>Compared with conventional variable voltage (VV) drive, VVVF drive could save energy by about 10%.</p>
<ul style="list-style-type: none"> Lift with synchronous motor with permanent magnets 	<p>Compared with asynchronous motors, the permanent magnet synchronous motors could save energy by about 30-50% as a result of high power factor (~0.9) and the elimination of excitation current [8].</p>
<ul style="list-style-type: none"> Lift with motor drive system <ul style="list-style-type: none"> - either gearless type or planetary gear type 	<p>The elimination of gear improves the energy efficiency as gearless drive has no gear transmission loss.</p> <p>Planetary gears can also be used to replace the low efficiency worm gears. By utilizing planetary gears, an overall annual savings of about 34% could be achieved when compared with worm gear system [8].</p>

2.6.2. APPROPRIATE ZONING ARRANGEMENT

Design appropriate arrangement of lift zoning which will subdivide the floors of the premises into clusters of stops to be served by different lift cars.

POINTS TO NOTE

- It is advisable to limit the number of start/stop cycles for a lift car to reduce the energy loss during start/stop cycle of lift car. This can be achieved through appropriate lift zoning.
- Appropriate lift zoning will not only improve the energy performance of lift system but also improve the handling capacity and the quality of service due to shorter waiting time.
- However, it is important to note that poor zoning arrangement can result in long average waiting time and unnecessary wastage of energy. For example, when a lift system is arranged to serve even/odd number floors, if the waiting time is too long, passengers are more likely to call for both lift systems. This will cause unnecessary wastage of energy.

2.6.3. SLEEP MODE FOR LIFT

Design lifts to go into sleep mode where lift will automatically switch off the lights and ventilation fan when the lift is idling. As most of the lift has considerable idling time during off-peak hours, putting the lift into sleep mode will save energy.

2.6.4. INTELLIGENT LIFT CONTROL

Design group control system that are able to assign the hall calls to individual lift in the way best suited to the existing traffic in order to achieve the maximum possible handling capacity. The system should be able to adjust the lifts operations in accordance with the peak and off-peak traffic flow.

POINT TO NOTE

- A good quality group control system must distribute the cars equally around the zone in order to provide an even service at all floors. Also it is important that only one car be dispatched to deal with each landing call.

2.6.5. LIFT CAR DECORATION

Light weight material should be designed for lift car decoration. The interior decoration in the lift car can lead to energy wastage as extra energy has to be consumed to move it up and down the lift shaft to carry this extra dead weight.

POINT TO NOTE

- The use of marbles, granites or other heavy materials will significantly increase the dead weight of the lift car and hence deteriorate the energy performance of the system.

2.6.6. ENERGY EFFICIENT LIGHTING


Energy efficient lighting should be used inside the lift car. Refer to Section 2.5 on lighting for details on the choice of energy efficient lighting.

2. ENERGY EFFICIENCY

2.6.7 EFFICIENT ESCALATOR

Design escalator with slow down features such as the motion sensor installed at the foot panel. The escalator will oscillate in a slow-mode when not in use and the escalator will be activated to normal speed when the user steps onto the foot panel of the escalator.

Normally, the motor drive system of escalator is running all the time regardless of the load condition of the escalator. Hence, electricity is continuously consumed even when there is no passenger on the escalator. Much energy is wasted if the number of passengers is widely fluctuating.

Escalators with slow down feature	Potential saving
	Adjusting the speed of the escalator to slow down when not in use can save energy of up to 30%.

2.7. ELECTRICAL SUB-METERING

To achieve energy efficiency, it is important to ensure that energy used by each operation unit is properly accounted for. Hence, a good sub-metering system should be established.

Sub-metering should be provided for substantive energy uses within the building (greater than 100KVA). For a typical office building, this should include separate metering for car park, chillers, air handling fans, lifts and common area lighting and power.

The readings taken can help to compile a better picture of building energy consumption and let building owners know how much electricity is consumed by those substantive energy intensive equipment. This improves the awareness of building owners on the importance of energy management.

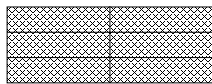
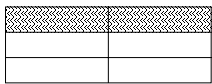
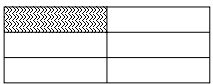
2.8. GREENERY

The use of greenery such as landscaping, rooftop/sky garden and green roof (intensive, extensive or hybrid system) can alleviate urban heat islands through shading and evaporative cooling. The plants also provide a green and more pleasant environment.

To encourage skyrise greening, URA has reviewed its guidelines on sky terrace to provide development with additional gross floor area. This incentive will help to offset the cost of constructing sky terraces.

To establish an accounting and planning tool for greenery provision, the Green Plot Ratio Study Committee was initiated in 2002. The green plot ratio will be used to measure greenery provision in building development. It takes into consideration the 3-dimensional volume covered by plants. However, the detailed Green Plot Ratio calculation and list of Leaf Area Index of plant are currently under development and are expected to be completed in early 2007. An example of green plot ratio calculation is shown in Table 3.

Table 3: Example of Green Plot Ratio

Plant	Grass	Shrub	Tree
Leaf Area Index (LAI)*	Grass LAI = 1 	Shrubs LAI = 3 	Trees LAI = 6 
Proportion Planted	6/6	2/6	1/6
Green Plot Ratio	$6/6 \times 1 = 1$	$2/6 \times 3 = 1$	$1/6 \times 6 = 1$

* The LAI value of grass, shrubs and trees shown are only quoted for the purpose of showing how green plot ratio is calculated. The actual figures may be subjected to changes.

Source of Green Plot Ratio : Dr Ong Boon Lay, NUS.

Reference: Ong, B. L., 2002, "Green plot ratio: an ecological measure for architecture and

2.8.1 LANDSCAPING

Where possible, landscaping should be designed at vacant places such as at the perimeter of the building, covered walkways etc. Landscaping not only beautifies the place, it also blocks off the heat from the sun and provides a cool shade. Besides that, it also retains rainwater and lowers runoff and this will reduce discharge into drainage system.

2.8.2 ROOFTOP AND SKY GARDENS

Rooftop and sky gardens could be used to enhance aesthetics of buildings and also to serve as solar and thermal insulation. Rooftop gardens are also known as intensive roof gardens. They are developed to be accessible for use. Regular garden maintenance such as mowing, fertilizing, watering and weeding is required.

A case study conducted in a multi-storey car park and a commercial building in Singapore revealed that the installation of rooftop gardens would significantly improve the thermal environment on building roofs [9]. Some of the measured thermal improvements due to the rooftop gardens are summarized in Table 4.

Table 4: Measured thermal improvements (not indoor environment) due to rooftop garden	
Thermal parameter	Range of reduction
Surface temperature of roof	0-31.0°C
Ambient temperature at 300mm height	0-4.2°C
Solar radiation at 300mm height	4.2-124.6W/m ²
(Source : Handbook on Skyrise Greening in Singapore by NParks and NUS)	



2. ENERGY EFFICIENCY

POINTS TO NOTE

- Roof structures should be designed to cater to the additional loads imposed by rooftop garden. When planning for load bearing capacity of roof structure, the following factors should be considered:
 - o Weight of vegetation when mature
 - o Weight of substrate material after consolidation and saturation
 - o Weight of stagnant water (e.g. at the substrate) due to drainage failure
- Building owners should be aware of the roof loading restrictions and avoid future improper relocation or additional planting in areas not designed to accommodate the additional weight.
- Plants selection is important to ensure the success of roof top gardens. The Handbook on Skyrise Greening in Singapore by NParks and NUS shows the types of plants suitable for intensive rooftop gardens.
- Sufficient depth should be provided to ensure the healthy growth of trees and plants selected. For example, the following depths of substrate are required for different plants:
 - o Groundcovers and shrubs
0.3-0.5m depth
 - o Trees with mature heights of 8-10m
1-1.5m depth

2.8.3 GREEN ROOF

Green roofs can be used to enhance aesthetics of buildings and their surroundings. It also reduces glare and provides solar and thermal insulation. Green roofs may be of the following types:

- o **Extensive green roof** has a thin layer and lightweight-growing medium, draught tolerant plants and requires little or almost no irrigation and maintenance.
- o **Intensive green roof** is also known as rooftop garden and it is discussed in section 2.8.2.

Green roofs should be designed to require a low level of maintenance through careful plant selection.

A case study conducted in a HDB multi-storey car park in Singapore revealed that the installation of green roofs would significantly improve the thermal environment on building roofs [10]. Some of the measured thermal improvements due to green roofs are summarized in Table 5.

Table 5: Measured thermal improvements (not indoor environment) due to green roofs	
Thermal parameter	Maximum reduction
Surface temperature of roof	19.4°C
Ambient temperature at 300mm height	5.9°C
Reflected global radiation at 500mm heights	247W/m ²
(Source: Research project by NParks and NUS)	



POINT TO NOTE

- Plants selected should be hardy, non-aggressive and self generative. To ensure maximum benefits of green roof, areas of coverage by plants and vegetation should utilize the maximum floor area. A publication by NParks titled "A Selection of Plant for Green Roof in Singapore" shows the types of plants suitable for green roofs.

Hardy Plants Suitable for Green Roofs



2.9 CASE STUDY

The Nanyang Polytechnic was awarded Green Mark Platinum in 2005. A measurement of energy consumption of the building showed an EEI of below 150 KW/m²/yr. The following main energy efficient features were implemented.

PASSIVE DESIGN

Building Orientation

- Principal facades with windows are of north-south orientation
- Minimum surface areas and windows on west and east facades
- Service cores and staircases are located in the eastern and western sectors of buildings

Typical facades facing north & south



Typical facades facing east & west



Sun-shading

- All windows are provided with external sun control overhangs

2. ENERGY EFFICIENCY

PASSIVE DESIGN

Facade Materials

- Glass windows are covered with low-e heat films
- Use of cavity walls



Day Lighting and Natural Ventilation

- Central Atrium is designed as open space to allow natural ventilation and day lighting penetration
- Amphitheatre is designed with special light-coloured Teflon roof membrane to allow penetration of day lighting and spaces around the roof membrane and entrances facilitate natural ventilation.
- Covered link-ways and link-bridges allow natural ventilation and day light penetration through cross ventilation opening at both sides.
- Non air-conditioned canteens are naturally ventilated and allow diffused day light from skylights.

Central Atrium



Amphitheatre



Canteen



Covered link-ways and link-bridges



PASSIVE DESIGN

Landscaping & Rooftop Gardens

- Gardens & courtyards are inter-spaced between buildings
- Rooftop gardens
- Water features incorporated in landscaping

Fountain Plaza



Bonsai & Orchid Garden



North Garden



South Garden



2. ENERGY EFFICIENCY

ACTIVE DESIGN

Air-conditioning System

- District cooling system
- VSDs on chilled water pumps
- VAV system with VSDs on AHUs
- Intelligent Building Management System (BMS) with chiller plant system control to maximize chiller efficiency
- Independent VRV for areas requiring 24 hours air-conditioning
- Motion sensors fitted at gyms and selected facilities

District cooling



VSD on chilled water pump



Zoning of air-conditioning areas



VRV

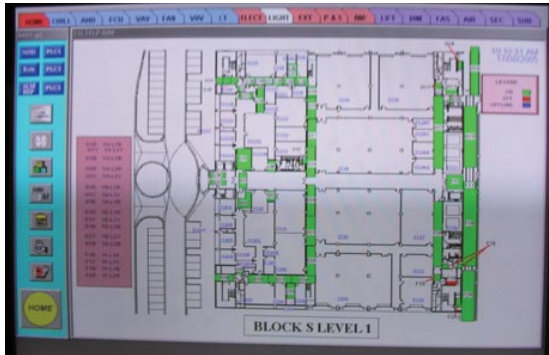


ACTIVE DESIGN

Lighting

- High frequency electronic ballast
- Intelligent BMS to control scheduling of lighting
- Zoning
- Where applicable, photocells to control exterior lighting
- Motion sensors fitted at toilets and selected facilities
- In-house energy saving landscaping lighting (see details in Section 6 on Innovation)

Zoning of lighting



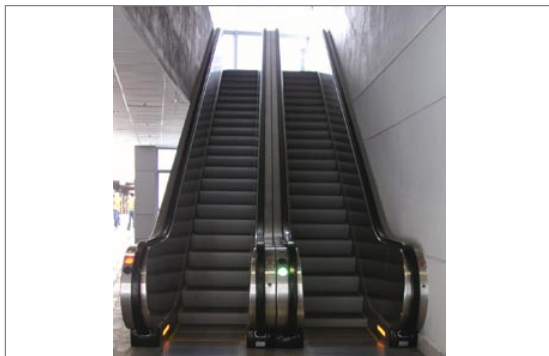
Motion sensor used in toilet



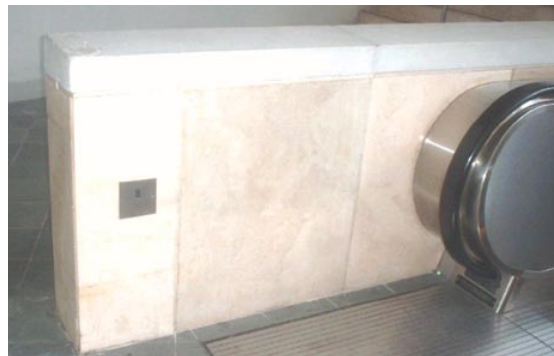
Escalators

- Variable speed drive escalators

VSD escalator



Motion sensor at escalator landing



Electrical Sub-metering

- BMS is used to monitor various sub-meters installed in the campus