- Please contact me at 27666144 or eewclo@polyu.edu.hk if you like to have one of these talk to be carried in your schools for your students.

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Energy Efficiency in Building - Management and Technology

1/Dec/2008
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Recent News

- **花五千萬搞節能　每年卻多付千萬電費**
  審計署報告：機電署總部變　電先鋒
- 【本報訊2008-11-27】審計署踢爆政府新建大樓「環保」之說，自稱「節能先鋒」的機電工程署總部大樓，原來是「用電先鋒」。雖然斥5,000萬元建設再生能源設施，用電量反較前大增43%。自誇設計環保的廉政公署大樓，用電量也較預期多115%。學者批評玻璃幕牆令室溫提升，浪費電力，有廉署高層透露每日承受西斜之苦。　記者：翁煜雄、麥志榮、馮永堅

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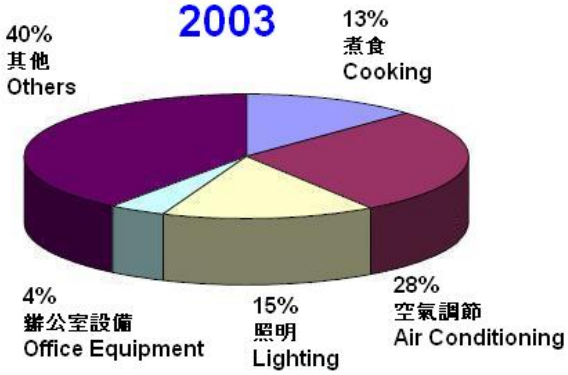
Energy Consumption Profile of a typical Office Building



Building Energy Saving Strategies

- Active Technologies
- Passive Technologies
- Operation & Management Aspects

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Active Technologies

- Energy Efficient lighting
- Lighting dimming
- Light sensors, occupancy sensors, timer
- Digital lighting systems
- Smart windows
- Variable speed drive for lifts, escalators pumps and A/C systems
- A/C system of higher CoP
- Ice storage cooling systems
- SCADA
- Fuel cells
- Intelligent power bar
- Renewable energy systems

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Energy Efficient lighting

- Efficiency of lighting system is measured in *Luminous Efficacy*, with unit of lm/W, that means how many *lm* of light output from 1 *W* of electrical power input
- Note: there are *Lamp Luminous Efficacy* and *System Luminous Efficacy (or Circuit Efficacy)*
- The former only concerns the lamp bulb/tube only, the latter involve the whole lighting circuit (including the losses in the ballast).

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LAMP CHARACTERISTICS

	Standard Incandescent	Tungsten-Halogen	Fluorescent	Compact Fluorescent	Mercury Vapor	Metal Halide	High-Pressure Sodium	Low-Pressure Sodium
Wattage								
Average System Efficacy (lm/W)								
Average Rated Life (hrs)								
CRI								
Life Cycle Cost								
Fixture Size								
Start to Full Brightness								
Restrike Time								
Lumen Maintenance								

- Hence fluorescent tube or compact fluorescent lamp is more energy efficient than standard incandescent lamp or Tungsten Halogen lamp
- New types of fluorescent tubes: T5 and T4
- Newer types of lamps are Induction lamp and LED lamps

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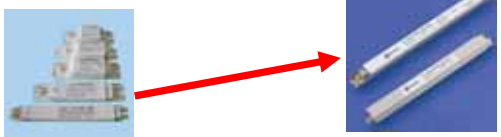
T5/T4 Fluorescent Tubes

- Old tubes are T12, T10, T9, and T8 (i.e. they have tube diameter of 12/8, 10/8, 9/8 or 8/8 inch)
- New types of fluorescent tubes are T5 and T4 (i.e. they have tube diameter of 5/8, 4/8 inch)
- They operate a slightly higher temperature and using newer types of phosphorus coating, hence has about 20-25% better efficacy.

Using Electronic Ballasts

- Using electronic ballast can improve the system luminous efficacy, although the lamp luminous efficacy remains the same, since the loss in electronic ballasts is much less than the conventional electromagnetic ballast.



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Induction Lamps

- Aside from the method of coupling energy into the mercury vapor, these lamps are very similar to conventional fluorescent lamps.
- Mercury vapor in the discharge vessel is electrically excited to produce short-wave ultraviolet light, which then excites the phosphors to produce visible light. While still relatively unknown to the public, these lamps have been available since 1990.
- The most common form has the shape of an incandescent light bulb. Unlike an incandescent lamp or conventional fluorescent lamps, there is no electrical connection going inside the glass bulb; the energy is transferred *through* the glass envelope solely by electromagnetic induction
- Advantages of induction lamp of long life (> 100, 000 hours) and higher *Efficacy (~ 150 lm/W)*

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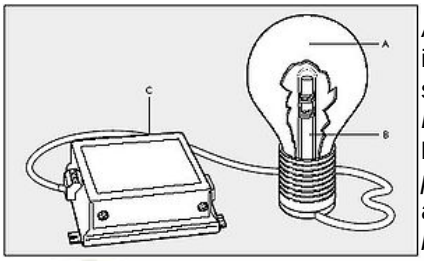

A Philips QL induction lighting system, where **A)** *Discharge vessel*, **B)** *Tube with power coupler* and **C)** *Electronic ballast*.

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LED (Light Emitting Diode)

- LEDs are small, solid light bulbs which are extremely energy-efficient (about 3 to 30 times more energy efficient than fluorescent tubes)
- Until recently, LEDs were limited to single-bulb use in applications such as instrument panels, electronics, pen lights and Christmas lights.
- Manufacturers have expanded the application of LEDs by "clustering" the small bulbs. The first clustered bulbs were used for battery powered items such as flashlights and headlamps.
- Today, LED bulbs are made using up to 36 bulbs per cluster, and encased in diffuser lenses which spread the light in wider beams.
- Now available with standard bases which fit common household light fixtures, LEDs are the next generation in home/office lighting.

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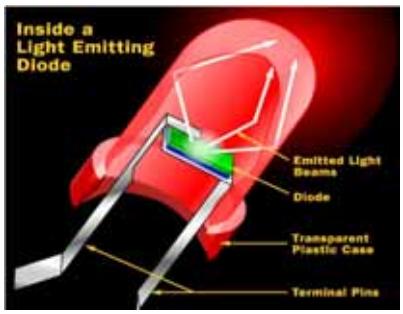

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Light Dimmers

- Modern power-electronic light dimmer can control the power delivered to lamp bulbs, and hence can dim the light according to the requirement, hence more energy efficient
- New models of dimmers can also control fluorescent bulbs/tubes. Example Spec. of these dimmers:
  - Continuous flicker-free dimming from 100% to 5%
  - Operates 1,2, 3 & 4 lamp compatible electronic ballasts for T8s, T5s and Compact Fluorescent Lights
  - Single point-of-control for use in low or high power applications
  - Specification-grade, preset designs or easy to operate, smooth slide or rotary controls
  - Available in single-pole or 3-way, in 5 colors
  - Fits in standard 2" deep single-gang switch box

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Light sensors, occupancy sensors, automatic timer

- These devices is for automatically turn the lights ON or OFF depends on ambient light level, time or/& date, any person in the room, etc.
- Hence it can turn off unnecessary lights and make system more energy efficient

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Occupancy Sensor

Digital lighting systems

- Digital lighting systems usually referred to the DALI (*Digital Addressable Lighting Interface*) system.
- That means *each* lamp can be addressed *individually* and hence ON & OFF (or in some cases dimmerable) *separately*.
- Hence provide a high flexible light arrangement to suit the current condition.
- It use digital communication bus, thus it largely reduce the complication & messiness in wiring.

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DALI

- **DALI** is an International Standard (IEC 62386) for the control of electronic ballasts, transformers, LED's, emergency lights and exit signs in an easy to manage control system.
- By combining DALI control networks on an Ethernet network you can scale your lighting control system from a fitting, to a floor, to a building and beyond.
- The **DALI CONTROL** system consists of distributed intelligent controllers spread around a building on an Ethernet network. Each controller uses time schedules, pushbuttons, switches and sensors to control lighting on DALI communications loops.

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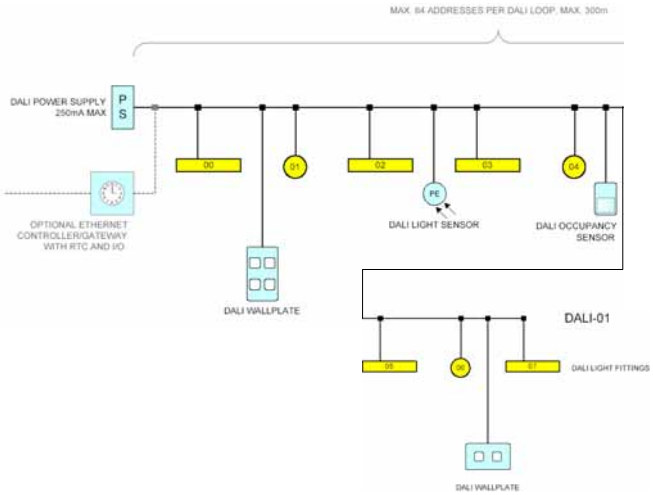

Addition benefits of lighting energy saving

- Note: For fully air-conditioned office, any amount of energy saving in the lighting system usually implies the same or even higher amount of energy will also be saved in the air-conditioning system of the office.

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Smart Windows

- It may include
  - Electronic curtains - The curtain can be open/closed or the blind blades can be rotated automatic to control the light to enter the room according to external lighting conditions.
  - Switched glass– the transparency of the glass can be controlled electronically

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Switched glass

- 3 major technologies
  - electrochromic devices
  - suspended particle devices
  - polymer dispersed liquid crystal PDLC devices

  (technologies similar to those of LCD displays on watches/calculator, and on those LCD panels on LCD projectors).

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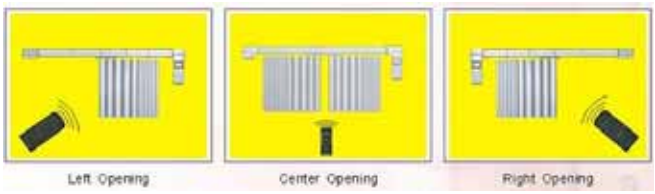
Electronic curtain system allows both automatic control and remote manual control



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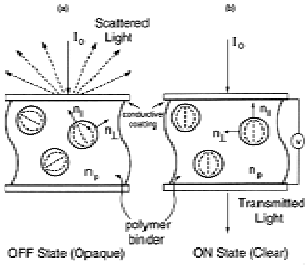
PDLC Device



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Variable Speed Drives (VSD)

- Very useful for lifts, escalators, pumps and A/C systems, where motors are used, and they need to run at variable speed
- Before having these VSDs, these motors have to run at fix speed and then use **mechanical** means to change the speed of the final object, hence not very energy efficient.

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VSDs

- The speed of AC motor changes with the frequency of the applied voltage, these VSD have an power electronic converter (called **Inverter** in this case) to convert the fixed 50Hz of the supply mains to any frequency between 0 to say 100 Hz, hence change the speed of the motor electrically.
- In case of lifts and other traction drive systems (say MTR), these VSDs also provide re-generation during braking, make the system even more energy efficient

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VSD = Inverter + AC motor

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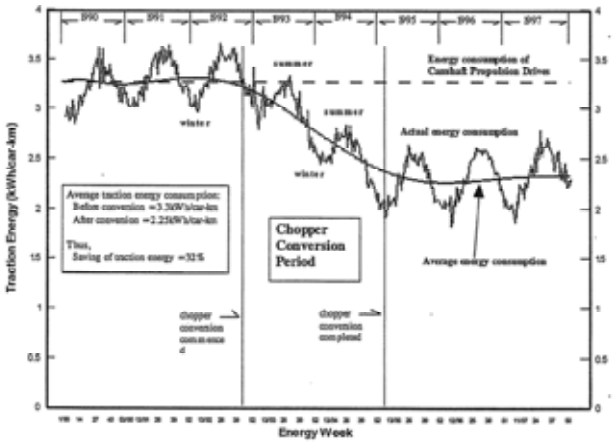
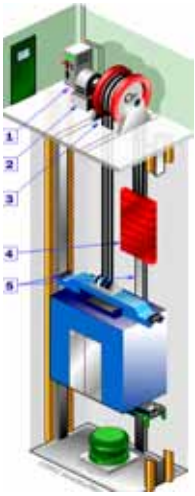
Energy saving by VSD in MTR





Other than braking VSD of lift system will also regenerate when descending a heavy loaded car or raising a nearly empty car

- Note: Weight of the counter-weight (4) is about the empty car + 40% of full-load passengers

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A/C system of higher CoP

- The **coefficient of performance**, or COP (sometimes CP), of a air-conditioning system is the ratio of the heat moved from at the cool reservoir to the supplied electrical power.
- New model of A/C system use inverter driven pumps & compressors, refrigerants of higher thermal capacity, more stable thermal insulation, more accurate digital control etc. and hence higher CoP
- Use occupancy sensors to control the A/C units.
- In general, the CoP increase, when one moves from window unit, to split unit, to central air-conditioning system, to *district cooling system*

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District Cooling System

- At a central refrigeration plant, chilled water is generated and supplied to a district to support the air-conditioning systems in buildings.
- Because of the large-scale production, together with the convenience of bringing in seawater for condenser cooling, the chiller plant is higher in efficiency than those in individual buildings.
- The customers can also use the building space of their own more effectively.
- The HK government is going to develop a district cooling system for the redeveloped Kai Tak area

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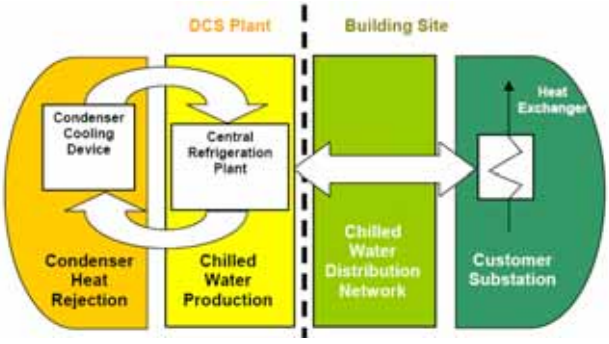
DSC Block Diagram



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Heat Recovery Ventilation (HRV)

- Add HRV unit to standard central air conditioning system or split-unit systems can improve the overall CoP the system
- The HRV unit per-cools the incoming fresh air (at outdoor temperature) by the exhaust air (at indoor temperature) of the room via the process of heat exchanging (not mixing).
- This will reduce the loading on the cooling coil of the system and hence reduce overall energy consumption.

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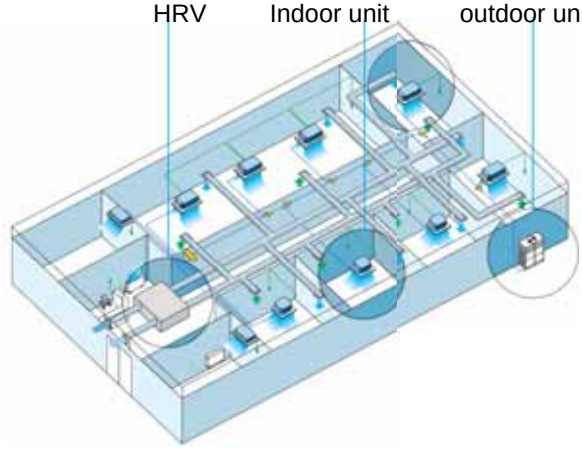
Applying HRV to split unit air-conditioning system:

HRV Indoor unit outdoor unit



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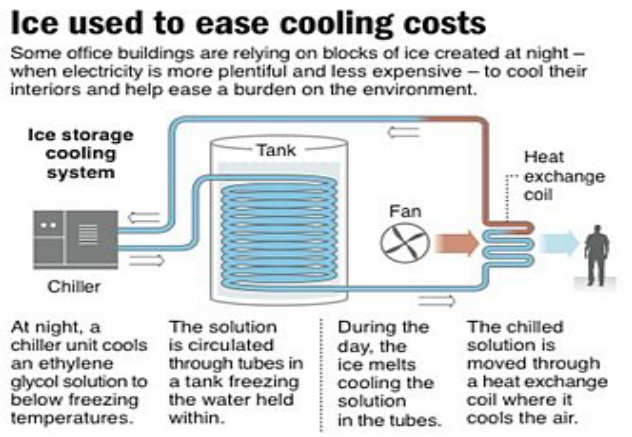
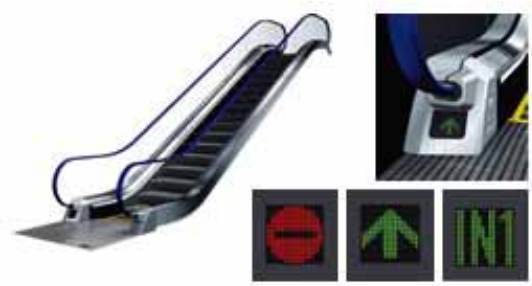
Ice Storage Cooling System



Adding sensors to escalators

- Whenever nobody use the escalators change it to stop mode or clawing mode



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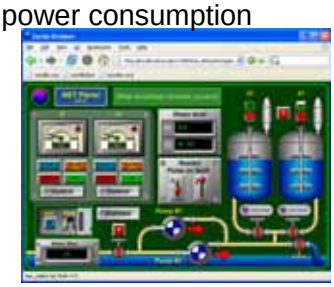
SCADA

- Install *Supervisory Control And Data Acquisition* (SCADA) system to monitor the electrical power flow and status of electrical switchgears within the building
- Help to trace the most power consumption equipment
- Help tracking the change in consumption profile
- Help in preventive maintenance



Fuel cells

- Fuel cells uses hydrogen (or hydrogen-riched fuel) to combine with oxygen (just from air) chemically to form water and output heat and DC electricity from the cells (the opposite process of electrolysis!).
- Its current application in buildings is for UPS and standby emergency power, and hence to reduce air pollution from standby generators
- They are expensive and small in power as compared with conventional fossil fuel generators, current fuel cells are commercially available up to 250kW per module.

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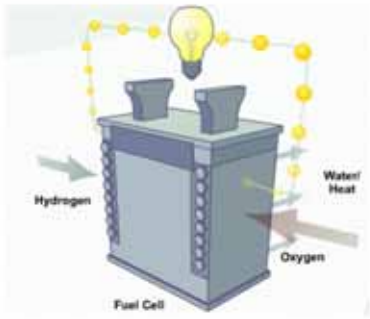
How fuel cell works



Large fuel cell ~250kW

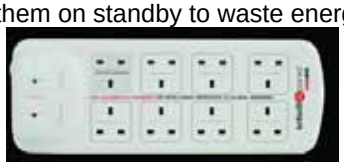
Modular in nature, can operate a few of them in parallel.

Intelligent Power bar

- Even equipment may have standby mode, they do consumption small amount of energy for a long long time. A study claimed that this costed HK$7,000M of energy per year for the whole world
- To save these “standby energy”, you may use “intelligent power bar”

Intelligent Power Bar

- Plug your desktop computer or laptop into the ***master socket*** on the Intelligent Power Bar and your peripheral devices (printer, monitor, scanner, etc.) into the other sockets of the Bar.
- When you turn on/off your computer, the Bar detects this and turns everthing else on or off accordingly.
- Saving you the hassle and stopping you from leaving them on standby to waste energy.



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Applying renewable energy systems: such as

- PV panels at roof tops or external façades
- Solar thermal system to pre-heat water for hot water system
- Small wind turbines at roof tops
- Micro hydro-generators in down feeding water supply systems and/or drainage systems.

Passive Technologies

- Orientations, forms and shapes of buildings
- Concept on OTTV – Overall Thermal Transfer Value
- Double/triple glazing
- Thermal reflective films on windows
- Block direct sunlight by installing awning, window shades and curtains.
- Nature lighting
- Nature Ventilation

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Orientation, forms and shapes of a building

- These together with the size and direction of windows will affect:
  - The use of natural lighting
  - The use of natural ventilation
  - The solar heat gain of the building
  - The OTTV value of the building
  - The energy consumption of the vertical transportation systems

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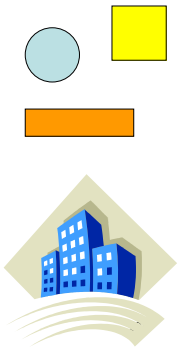
Tall or short building?

- Taller building ⇒
  - Easier in applying natural lighting and natural ventilation
  - But larger external surface area, hence generally higher heat loss/gain to/from exterior
  - Also more energy consumption in vertical transportation systems or water pumping systems

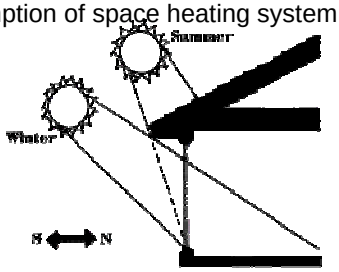
Round, square or rectangular plan?

- A more rectangular floor plan ⇒
  - Easier in applying natural lighting and natural ventilation
  - But larger external surface area, hence generally higher heat loss/gain to/from externior



Directions of windows

- Large south facing windows:
  - Lower heat gain in summer, hence reduce energy consumption of space cooling system
  - Higher heat gain in winter, hence reduce energy consumption of space heating system



- Should avoid large west facing windows

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OTTV" Overall Thermal Transfer Value

- the OTTV is an index for comparing the thermal performance of buildings. It is a measure of the average heat gain (average over a year) into a building through the walls and other surfaces and consists of three major components: (a) conduction through opaque walls, (b) conduction through window glass, and (c) solar radiation through window glass.
- Unit: W/m^2
- In HK, the building regulations require OTTV of a tower building < $35W/m^2$

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OTTV of a building affected by

- Thickness of external walls and roofs
- Materials used at external walls and roofs
- Directions of walls
- Size and directions of windows
- Type of windows/glasses, any overhangs and shading devices on windows

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$$OTTV_w = \frac{(A_w \times U \times \alpha \times TD_{EQw}) + (Af_w \times SC \times ESM \times SF)}{Ao_w}$$

where

A_w	=	Area of opaque wall, m^2
U	=	Thermal transmittance of opaque wall, $W/m^2°C$
α	=	Absorptivity of the opaque wall (Table 4)
TD_{EQw}	=	Equivalent temperature difference for wall, °C
Af_w	=	Area of fenestration in wall, m^2
SC	=	Shading coefficient of fenestration in wall
ESM	=	External shading multiplier
SF	=	Solar factor for the vertical surface, W/m^2
Ao_w	=	Gross area of external walls, i.e. $A_w + Af_w$, m^2

$$U = \frac{1}{R_i + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots + \frac{x_n}{k_n} + R_a + R_o}$$

x = Thickness of building material of the wall or roof or part thereof, m

k = Thermal conductivity of the building material, W/m°C (Table 1)

R_i = Surface film resistance of internal surface of the wall or roof, m²°C/W (Table 2)

R_o = Surface film resistance of external surface of the wall or roof, m²°C/W (Table 2)

R_a = Air space resistance, m²°C/W (Table 3)

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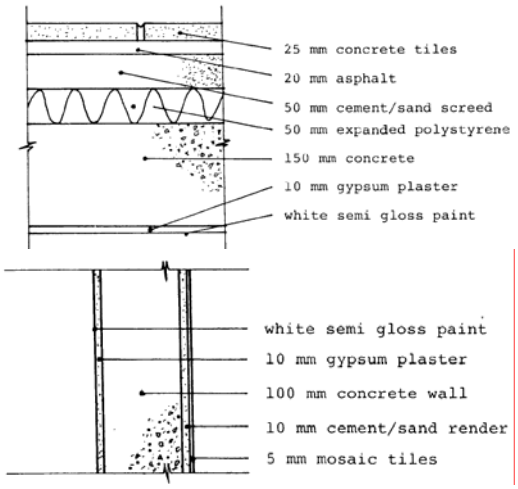
Material	Density kg/m^3	Thermal Conductivity (k) W/m°C
Asphalt, mastic with 20% grit	2350	1.15
Boards		
a) cork	145	0.042
b) hardboard high density	1010	0.144
c) mineral fibre	265	0.053
d) plasterboard	950	0.16
Brick (common)	1900	0.95
Concrete		
a) normal weight aggregate	2400	2.16
b) lightweight aggregate	1300	0.44
c) flat roof tiles or slabs	2100	1.10
Glass	2500	1.05
Mosaic tile cladding	2500	1.50
Insulating materials		
a) glass fibre mat or quilt	32	0.035

Examples of roof & wall



Higher performance Window

- High-performance window has low-emissivity glazing with visible transmissivity greater than 0.6 and solar transmissivity less than 0.4. This can reduce annual lighting operating energy by 20%. A further 20% reduction can be achieved if high-performance glazing is combined with daylight controls (by curtain, shading etc).

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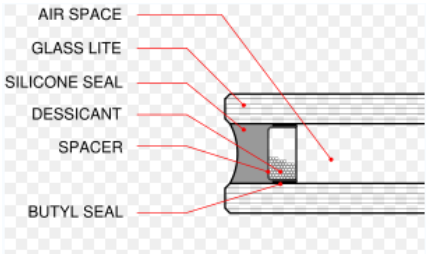
- Double or even triple glazing with low-emitivity glass can largely reduce the solar heat gain, reduce hear transfer and improve sound insulation, but maintain visibility.



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Comparison

Characteristic	Double glazing with coatings	Single glazing with coatings	Low emission double glazing	Single glazing without coating
Thermal transfer value (W/m²℃)	2.4-3.29	4.88-5.96	1.6-1.87	5.22-6.76

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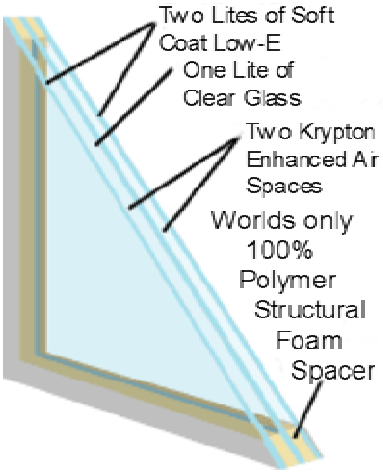
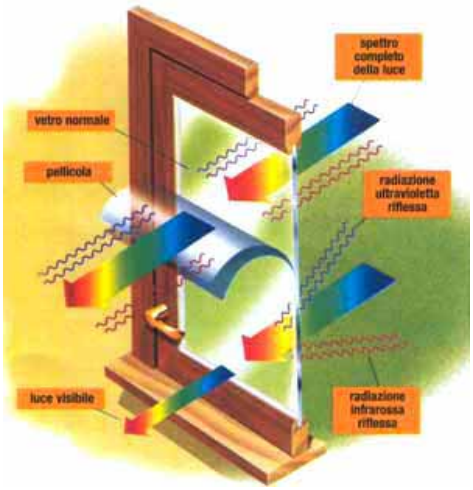
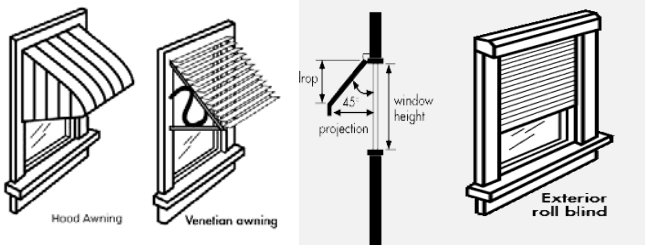
- Triple glazing



Solar reflective films

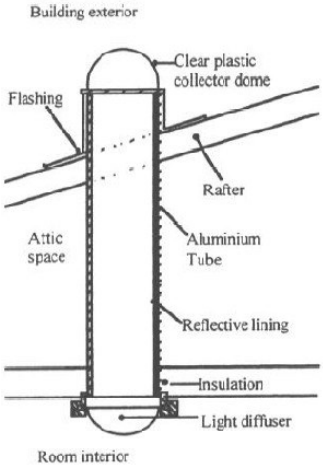


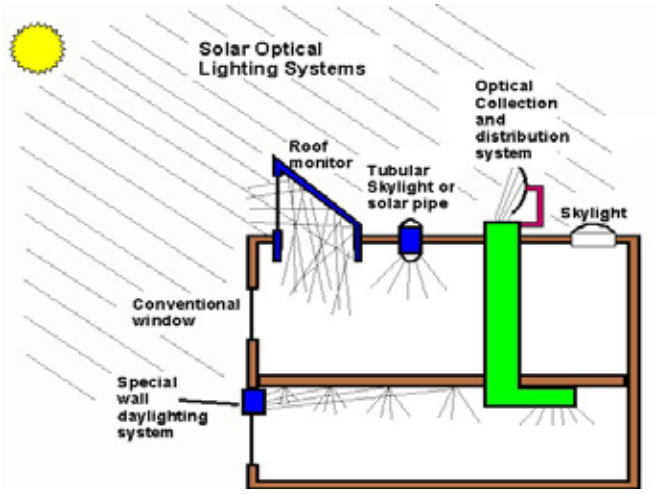
External Shading device to control the **direct** sun light



Interior curtain can do similar work, but not as effective.

Use of Natural Lighting





Example of Use of Natural Lighting

- On the top of the HSBC HQ building, a mirrored 'sun scoop' reflects sunlight down through the atrium to the floor of a public plaza below.

Large window with non-direct sun light is also a good use of natural lighting

More switching zones for lighting control

- Allow more flexible arrangements of lighting
- Can allow better combination use of electric light and nature light.
- Use more direct lighting, instead of indirect lighting

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Use of Curtain to Control the use of Natural Lighting

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Maximize Natural Ventilation

- Windows should be designed to admit natural ventilation. The most important design issue is whether the windows provide single-sided or cross-ventilation.
- Ventilation capacity depends on the area and vertical distribution of openings. These depend on the way the window opens.
- Horizontal pivot windows offer the highest ventilation capacity
- For single-sided ventilation, place them as high as possible to exhaust warm air at ceiling level.
- Air entering through the upper opening is directed toward ceiling, making night-time cooling more effective.
- Center vertical pivot windows have less ventilation capacity than horizontal pivot windows, but can act as wind scoops when wind direction is parallel to the building face.

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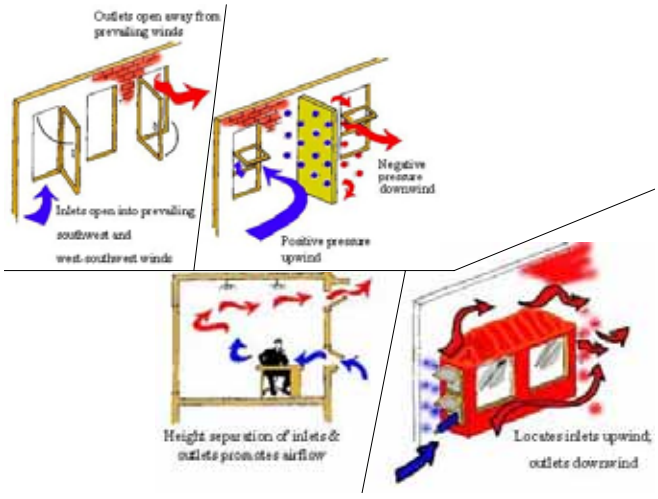

- Casement windows offer the same advantages as vertical pivot windows but are susceptible to gusts. If using casements to channel wind:
- Open into prevailing winds when used as inlets.
- Open away from prevailing winds when used as outlets.
- If not part of the window design itself, incorporate fins, overhangs or articulation to create high and low wind pressure areas, and to channel incoming air.
- Use vertical fins to improve natural ventilation of rooms with only one exterior wall. Provide two separate operable windows on upwind and downwind sides of fins, for inlet and outlet.
- Articulate the building facade (e.g., with bay windows) to create localized pressure differences. Place windows on adjacent or opposite faces of the protrusion as inlets and outlets.

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Operation & Management Aspects

- Lighting Systems
- Air-conditioning Systems
- PCs
- Refrigerator
- Promotional & administrative activities
- Monitoring of Energy Consumption & Usage
- Energy Audit

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The lighting systems

- Turn on/dim to the right amount of lighting
- Turn off lights whenever it is not used
- De-lamping some lamb blubs and/or tubes if the lux level is too high
- Add additional ***task lighting*** (e.g. table lights) if higher lux level is required at the desk, in stead of increase the ***general lighting***

- Regularly clean the lamp tube/blub, the interior and exterior of the lighting fixtures, and the walls.

- Replace a lamp tube/blub when it is near it end of its life, ***not*** till it fails

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The Air-conditioning systems

- Set to the right temperature settings for the activities in the room, say 25.5°C for light general office work.
- A decease of 1 °C in setting roughly decrease the energy consumption of A/C system by 10%.
- Turn-off A/C systems when it is not going to use in next 20 minutes

- If possible, turn-off the A/C system of a room, 15 minute before the end of the use of the room.
- Shorten the morning pre-cooling period of central A/C systems in cool days
- Program the starting of chillers of central A/C systems such that they are not turn-on at the same time.
- Close all the windows and doors whenever the A/C system is ON
- Manually use curtains to control the entering of direct sun light but allow the use of natural light

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- Use fans together with A/C
- Regular checking on windows & door seals for possible leakage air leakage
- Regular checking on pipe works of air-conditioning systems for water condensation and possible leakage of refrigerants
- Regularly clean air filters & air-vents, and maintenance of heating/cooling coils

Maximize ventilation

- Take advantage of natural ventilation by letting the trade winds enter windward windows and drawing warm air out of leeward windows.
- Install window fans in windows facing away from the prevailing wind to exhaust hot air from your home.
- Use circulating fans to create a wind chill effect that will make you more comfortable. Ceiling fans are considered the most effective. If you use air conditioning, a ceiling fan will allow you to raise the thermostat setting about 2˚C.
- Use spot ventilation to remove the heat while cooking (oven hood vent), while bathing (bathroom vent), and while running the clothes dryer (dryer vent).

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For your PCs

- Turn off the monitor if not going to use the PC for > 20 minutes.
- Turn off both the CPU and monitor if going to use the PC for > 2 hours.
- Check the PC comes with a power-down/sleep mode for the CPU/monitor.
- Note that screen savers are not energy savers.
- Plug your monitor and printer into a power strip and when not in use turn off the switch on the power strip.
- If you are planning on buying a computer, put energy consumption of the PC as one of the considerations.

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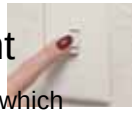
Your refrigerators

- Put hot food into the refrigerator after cooling it
- Take out food earlier for those need defrosting
- Try to open and shut the refrigerator as quickly as possible
- Try not to open and shut the refrigerator wastefully
- Don't too fully load the refrigerator, allow good air circulation inside
- Regularly check the door seal to ensure tightness
- Allow enough space around it for sufficient cooling
- Regularly clean the back space and the space around the compressor

For other electrical equipment



- If possible, turn off any electric appliance which is not in use, such as lights, printers, TVs
- Turning off/remove the charger from the power socket after you fully charged your NB computers/mobile phones/PDAs/Cameras /MP3
- Use energy labels as one of the guidelines in purchasing new office electric appliances

- Allow enough space around the equipment for sufficient cooling
- Regularly clean air inlets and out lets of the cooling fans of the equipment (if any)
- Regularly clean the heating surface of stoves, cookers to ensure good thermal contacts
- Regular maintenance by professional personnel

Promotional & administrative activities

- Enhancing the concept of energy saving among colleagues: putting stickers next to light switches, air-conditioning controllers, lift landing buttons, …
- Regular technical talks/social talks on energy conservation or related topics
- Encourage causal wear, no ties, …
- Let data of electricity bills transparent to all

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Energy Audit

- Carry out an energy audit to find out the consumption profile
- From the audit results find out where energy can be saved.

- Two public lectures in Energy Saving and Energy
- Open to public including teachers & students
- Free of charge, no pre-registration is required
- Attendance cert. will be issued.

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Conclusions

- Technologies are there, opportunities are there.
- It is time for us to act together to reduce energy consumption of the whole earth.
- Thank you for your attention!