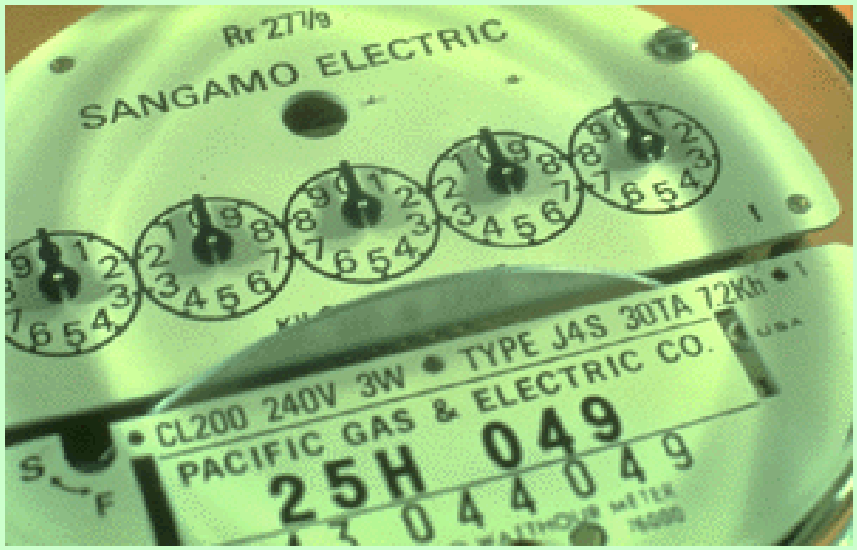
GEE5303 Green and Intelligent Building

http://ibse.hk/GEE5303/



Energy efficiency in buildings

Ir. Dr. Sam C. M. Hui

Faculty of Science and Technology

E-mail: cmhui@vtc.edu.hk

Jul 2016

Contents

- Why energy efficiency?
- Passive design
- Building envelope
- HVAC systems
- Lighting systems
- Other considerations

Why energy efficiency?

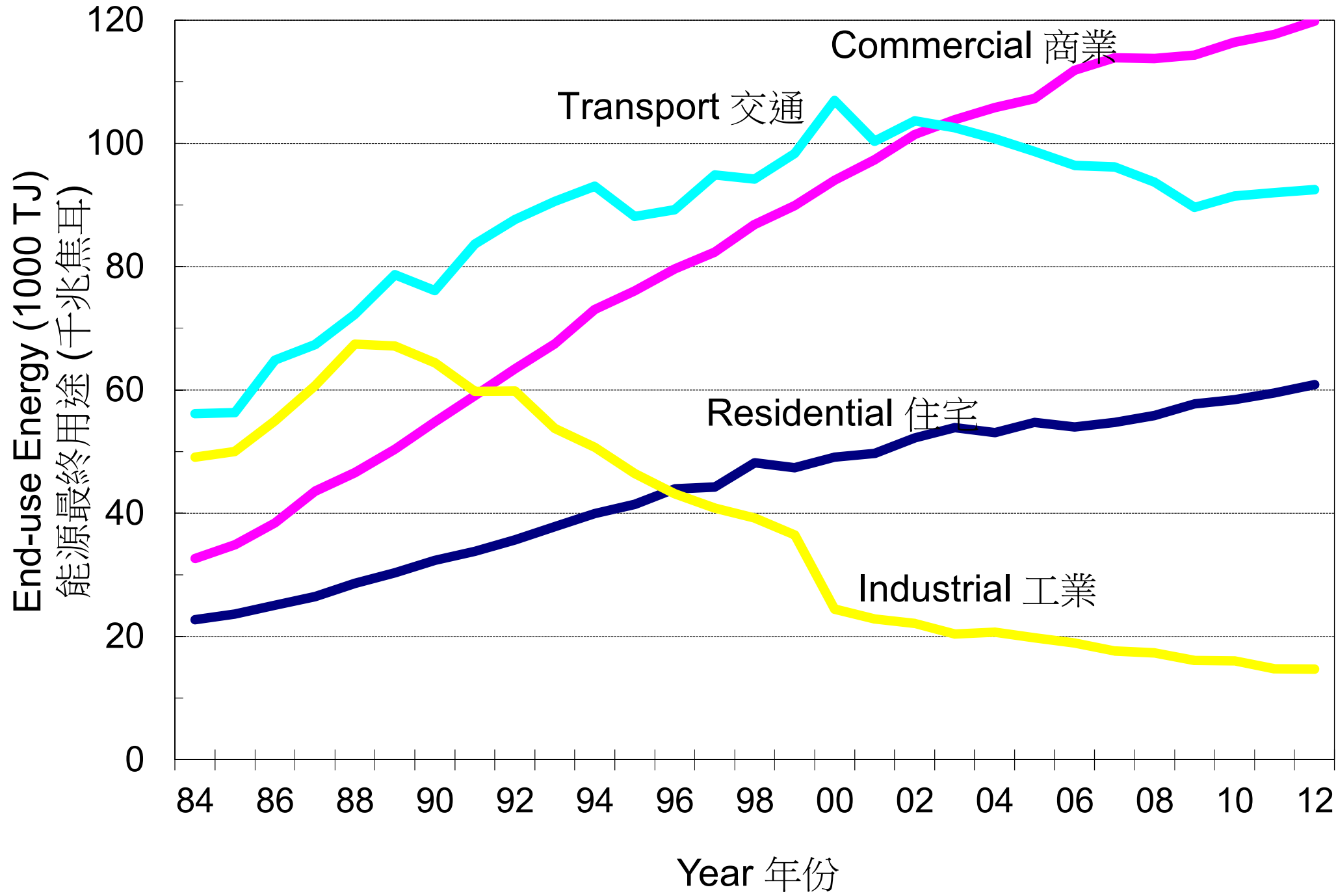
- **Energy** is important to every society
  - Economic, environmental & social impacts
  - It is also a key issue for ***sustainable development***
- Use energy …
  - Consume finite fossil fuels (oil, coal, natural gas)
  - Cause air pollution & environmental damage
  - Contribute to global warming
  - Cost money

Why energy efficiency?

- Buildings constitute 30-50% of energy needs
  - Residential + commercial + industrial
  - The potential for energy saving is large

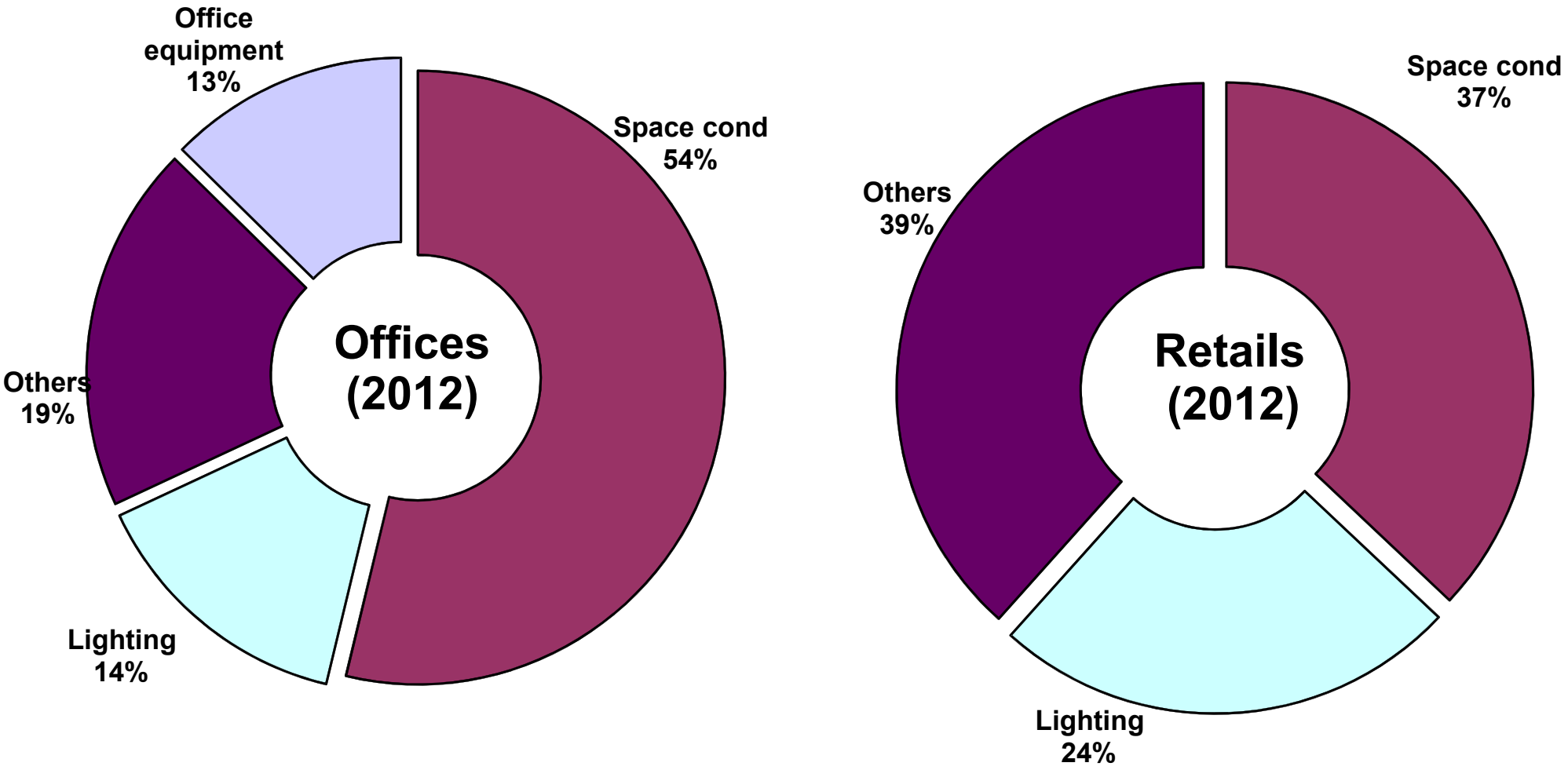
- The real cost of energy
  - Energy price, e.g. $ per kWh (electricity)
  - Environmental costs or externalities
    - e.g. $$ for pollution control & “repairing” of environmental damages
  - Need to internalise the (negative) externalities

See also http://en.wikipedia.org/wiki/Externality



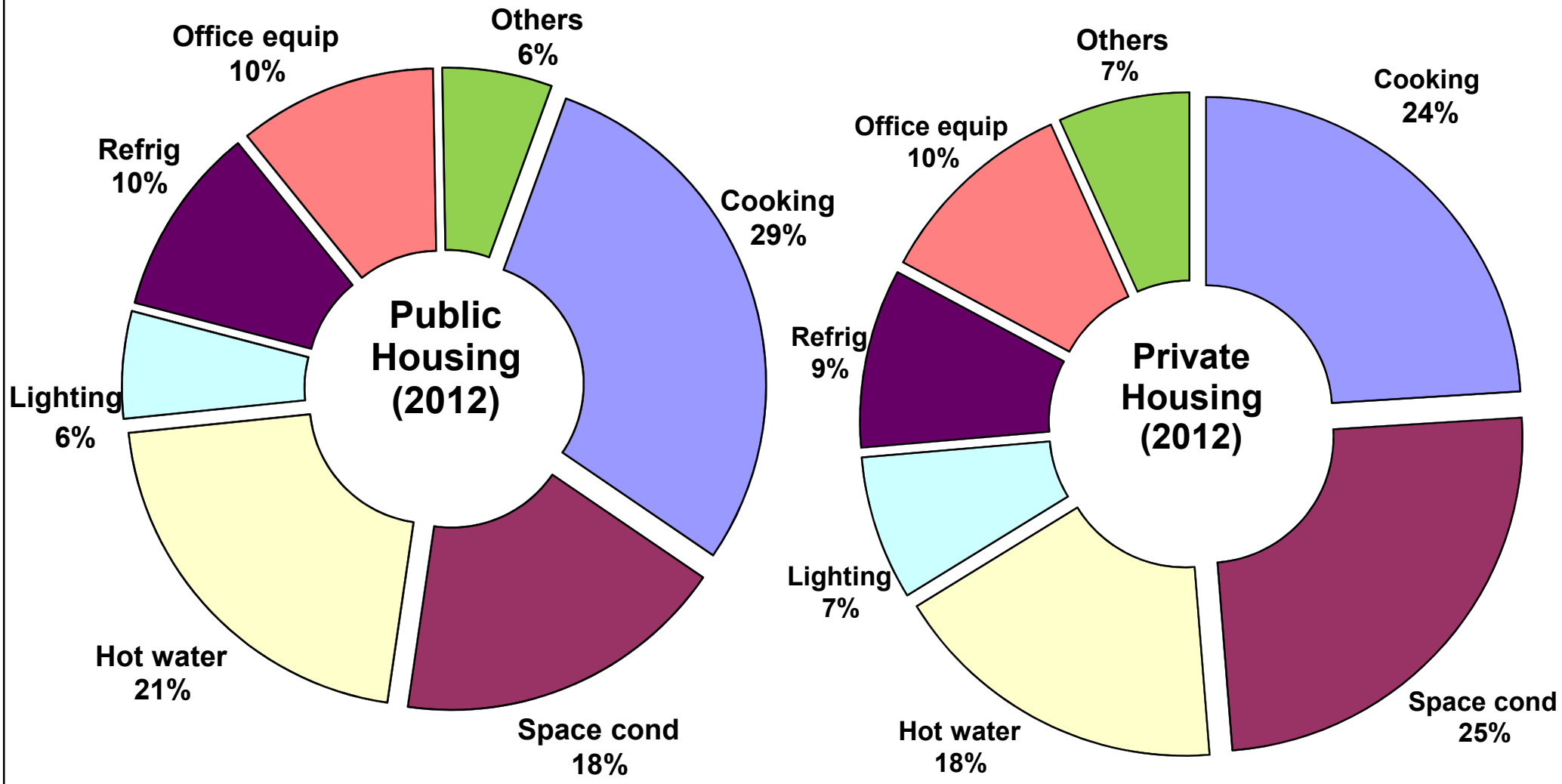
(Data source: EMSD) Energy end-use in Hong Kong by sectors, 1984-2012

What are the major energy usages?

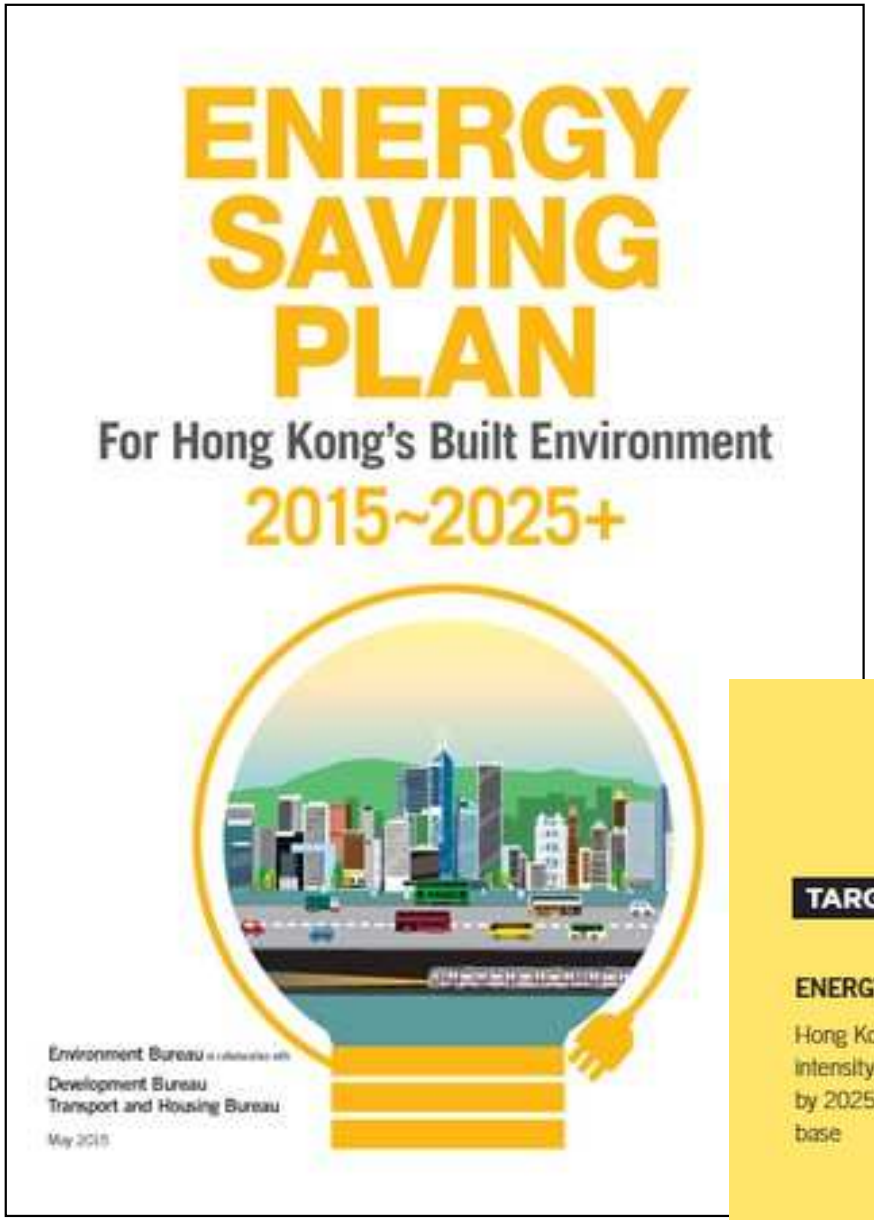


Energy consumption patterns in offices and retails
(Data source: Energy Efficiency Office, HK)

What are the major energy usages?



Energy consumption patterns in residential buildings
(Data source: Energy Efficiency Office, HK)



(Source: http://www.info.gov.hk/gia/general/201505/14/P201505140408.htm)

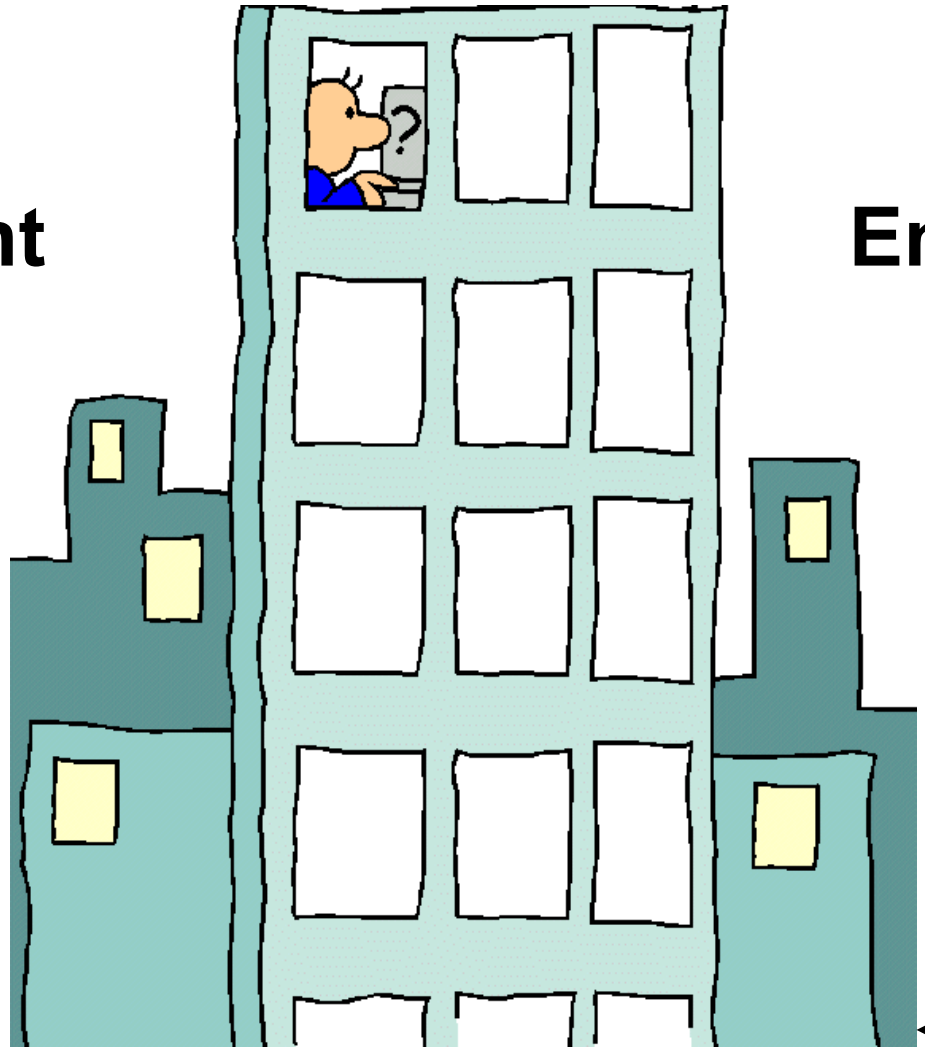
(Source: EMSD)

(See http://www.beeo.emsd.gov.hk for details)

Design of the built environment

Shelter

Outdoor Environment

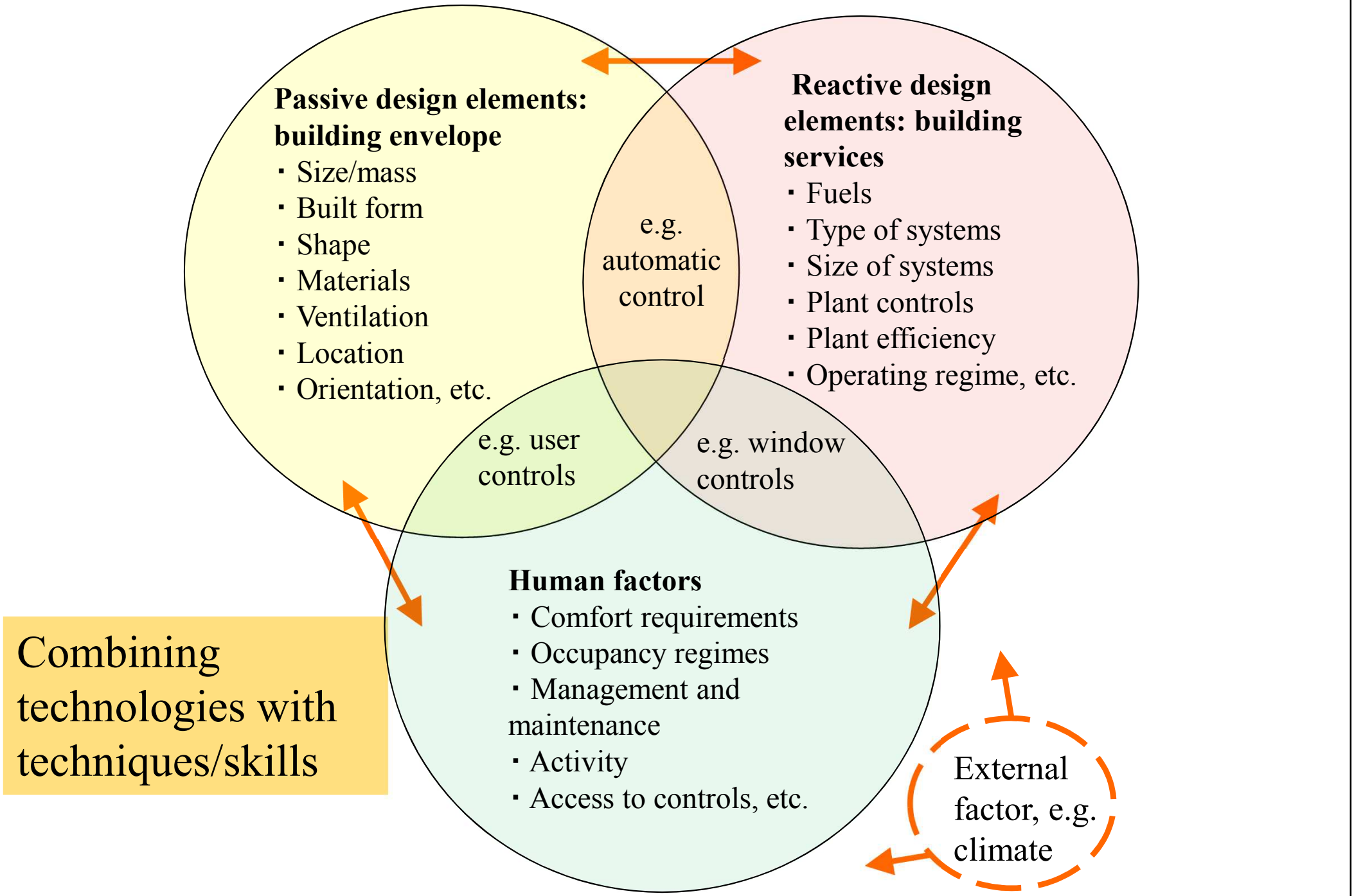


Human Environment

Do you know how to design energy efficient buildings?

Energy demand and energy use by the building and its building systems

← Energy supply to the building

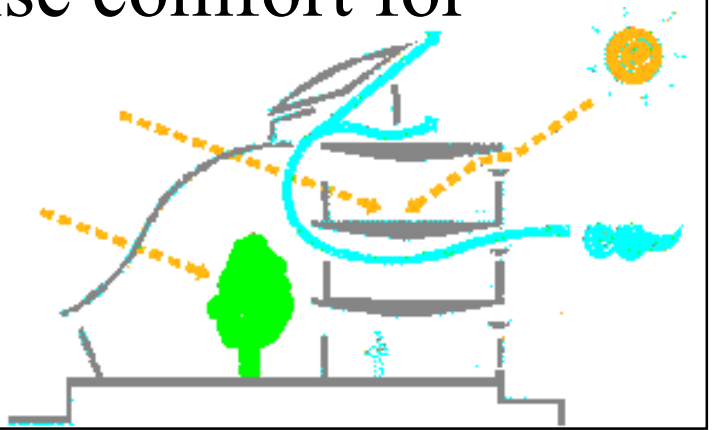


Key factors influencing energy consumption

(Adapted from Energy Efficiency in Buildings: CIBSE Guide F)

Passive design

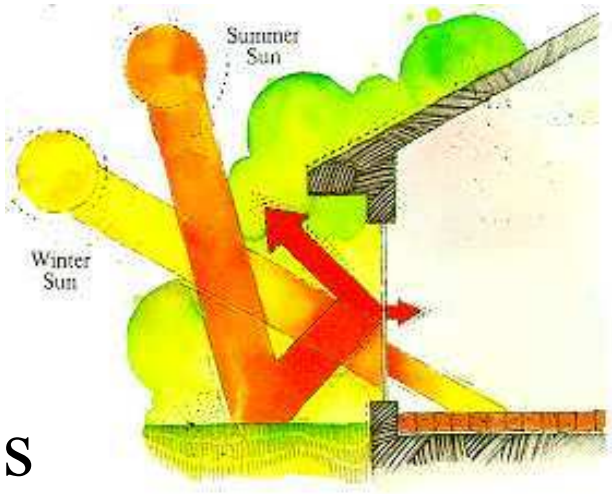
- Passive design (被動式設計)
  - Design the building and the spaces within it to benefit from *natural light, ventilation* and even temperatures
  - Ensure the fabric of the building and the spaces within it *respond* effectively to *local climate and site conditions* in order to maximise comfort for the occupants



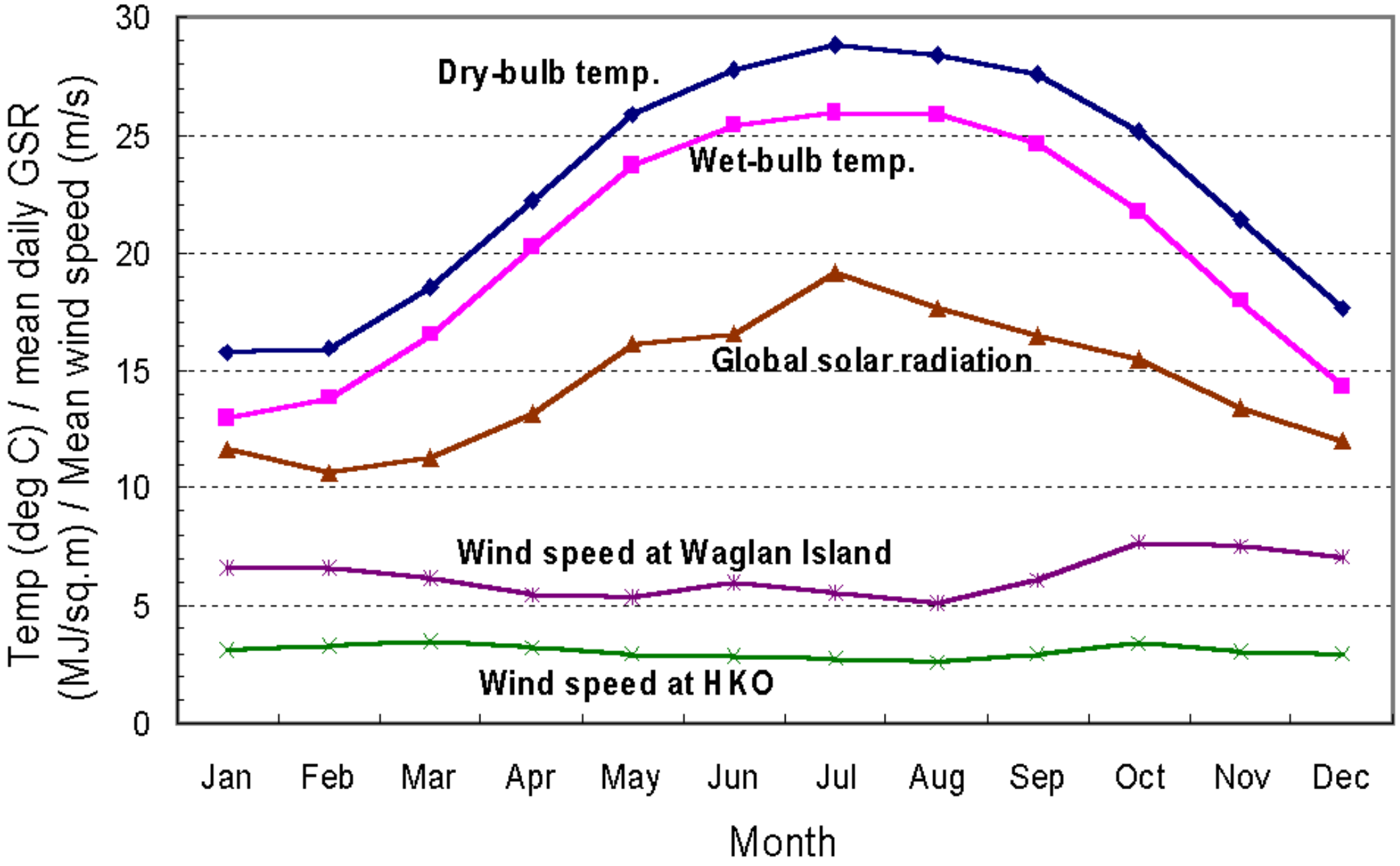
(Source: www.level.org.nz/passive-design/)

Passive design

- Key factors of passive design:
  - Climate and site analysis
  - Solar design and shading control
  - Correct orientation and use of windows
  - Use of thermal mass and insulation
  - Provision for ventilation (natural)
- Further reading:
  - Passive Cooling in Tropical Climates
    - http://www.btsquarepeg.com/sustainable/energy/passive-cooling-in-tropical-climates/

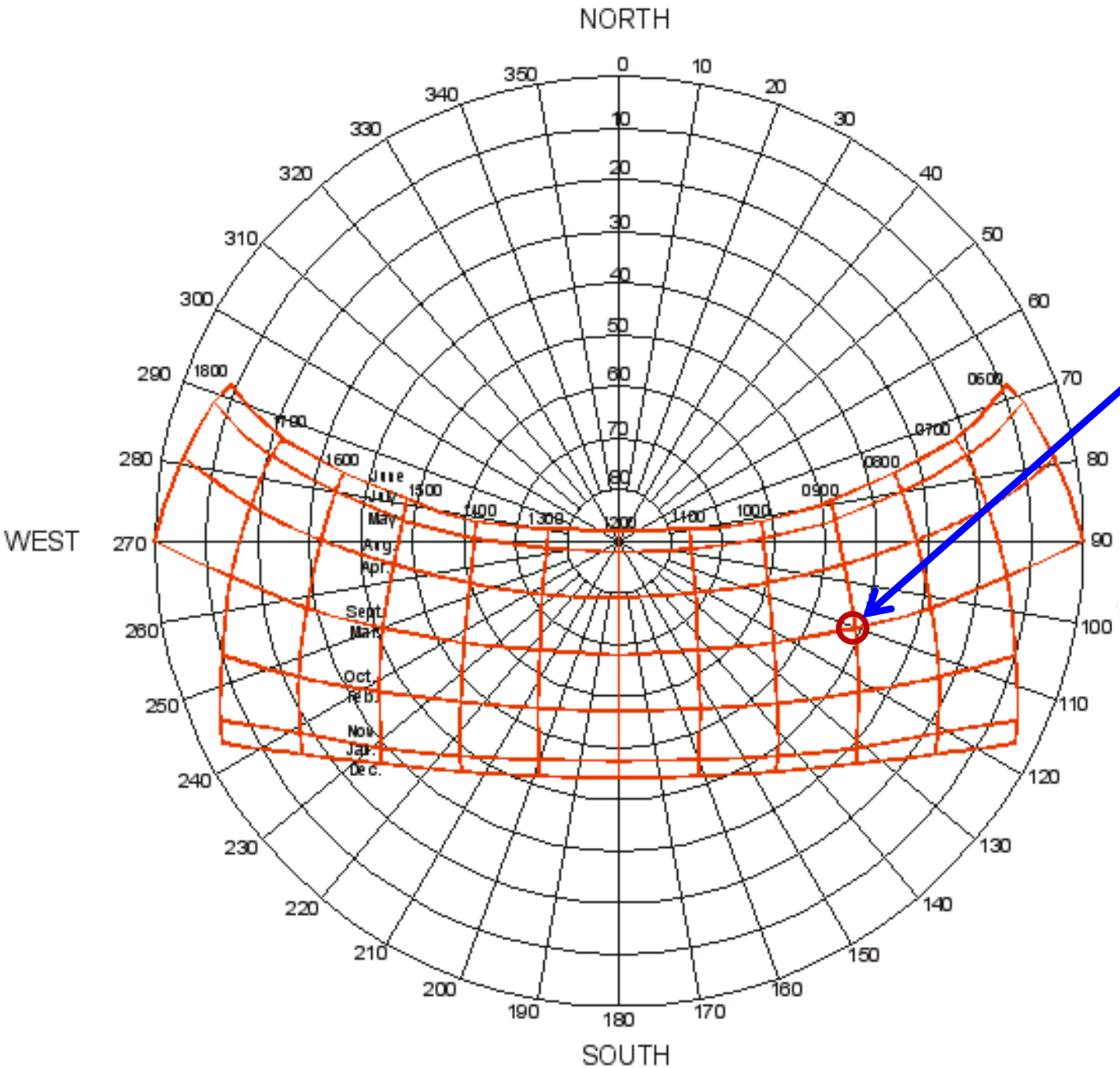


Major climatic elements of Hong Kong



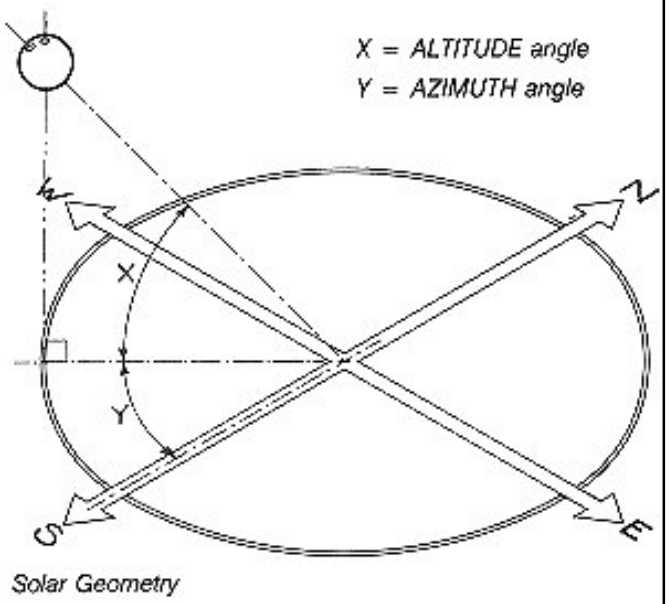
(Data source: Hong Kong Observatory)

Sun path diagram for Hong Kong (latitude 22.3º)



How to find the sun's position?

Example: 1 March at 9am
Alt = solar altitude = 41º
Az = solar azimuth = 110º

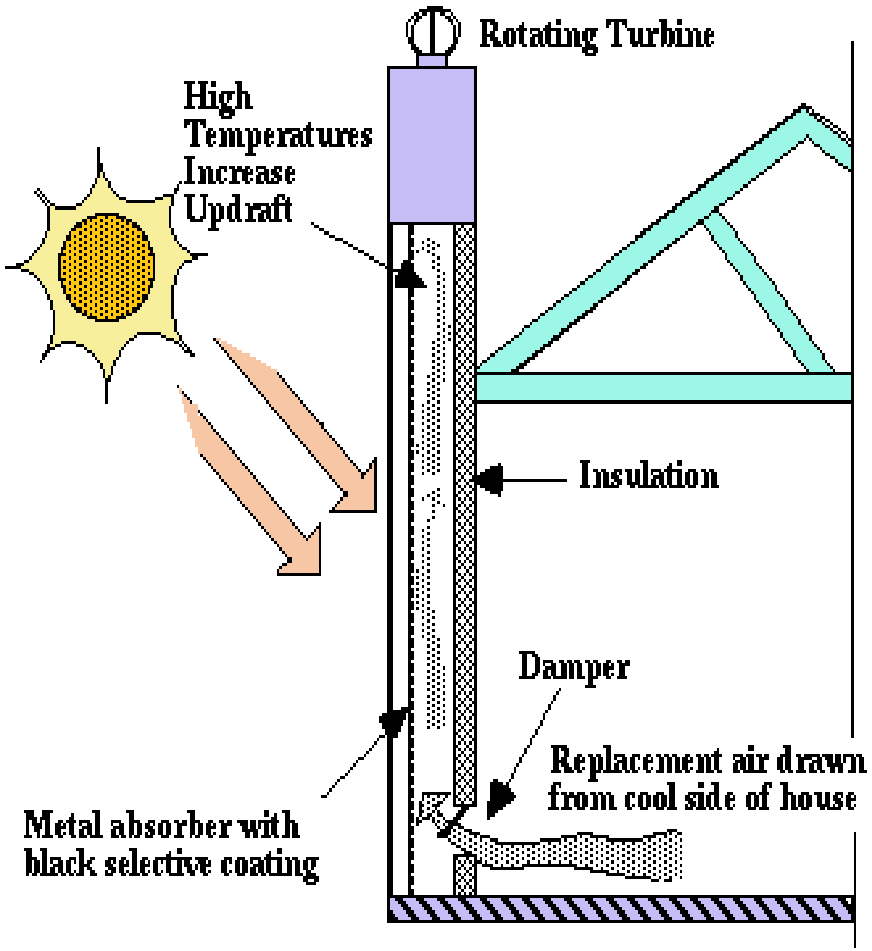


Solar Geometry

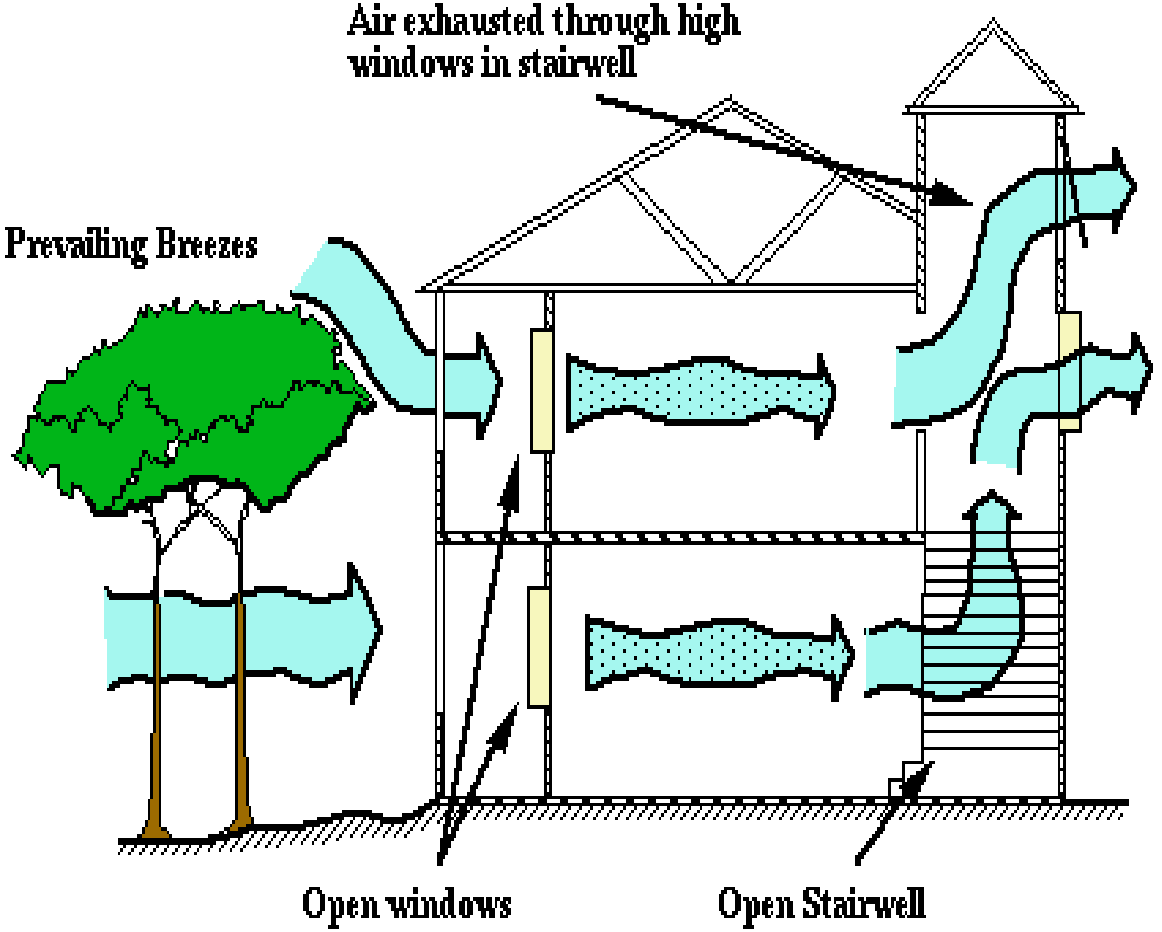
See also: Sunpath Diagrams, http://www.jaloxa.eu/resources/daylighting/sunpath.shtml
Sun Path Diagram Generator, http://www.horca.net/graphs/sunplot.php

Examples of passive cooling designs

(promote passive & natural cooling => reduce mechanical energy)



Thermal chimney

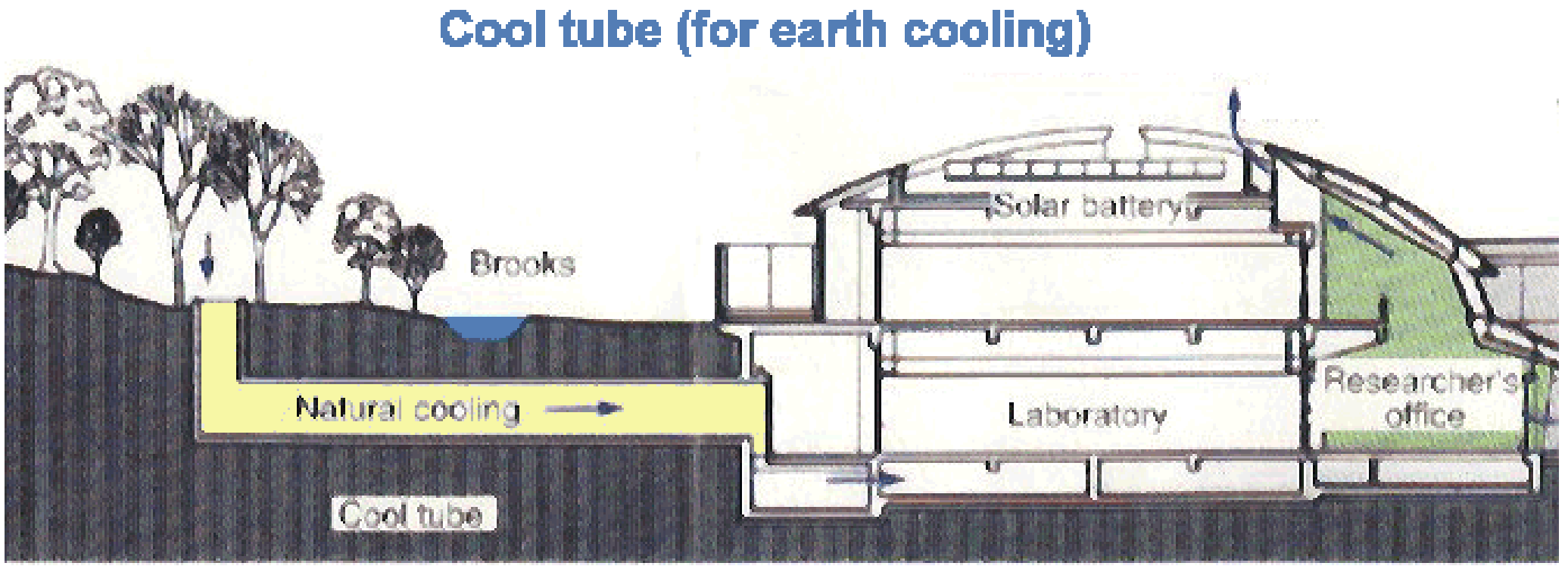


Natural ventilation

(See also: http://en.wikipedia.org/wiki/Passive_cooling and http://passivesolar.sustainablesources.com/)

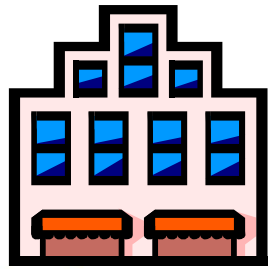
Examples of passive cooling designs

(outdoor fresh air cooled by the earth before entering the building)

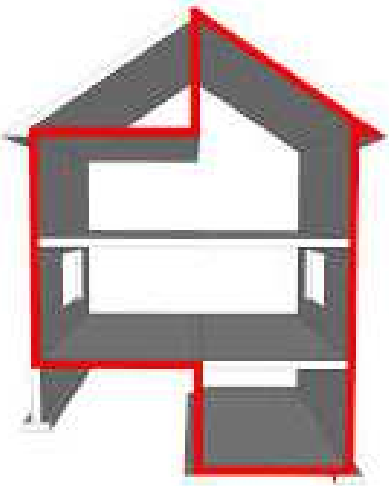


Earth tube cooling (Japan)

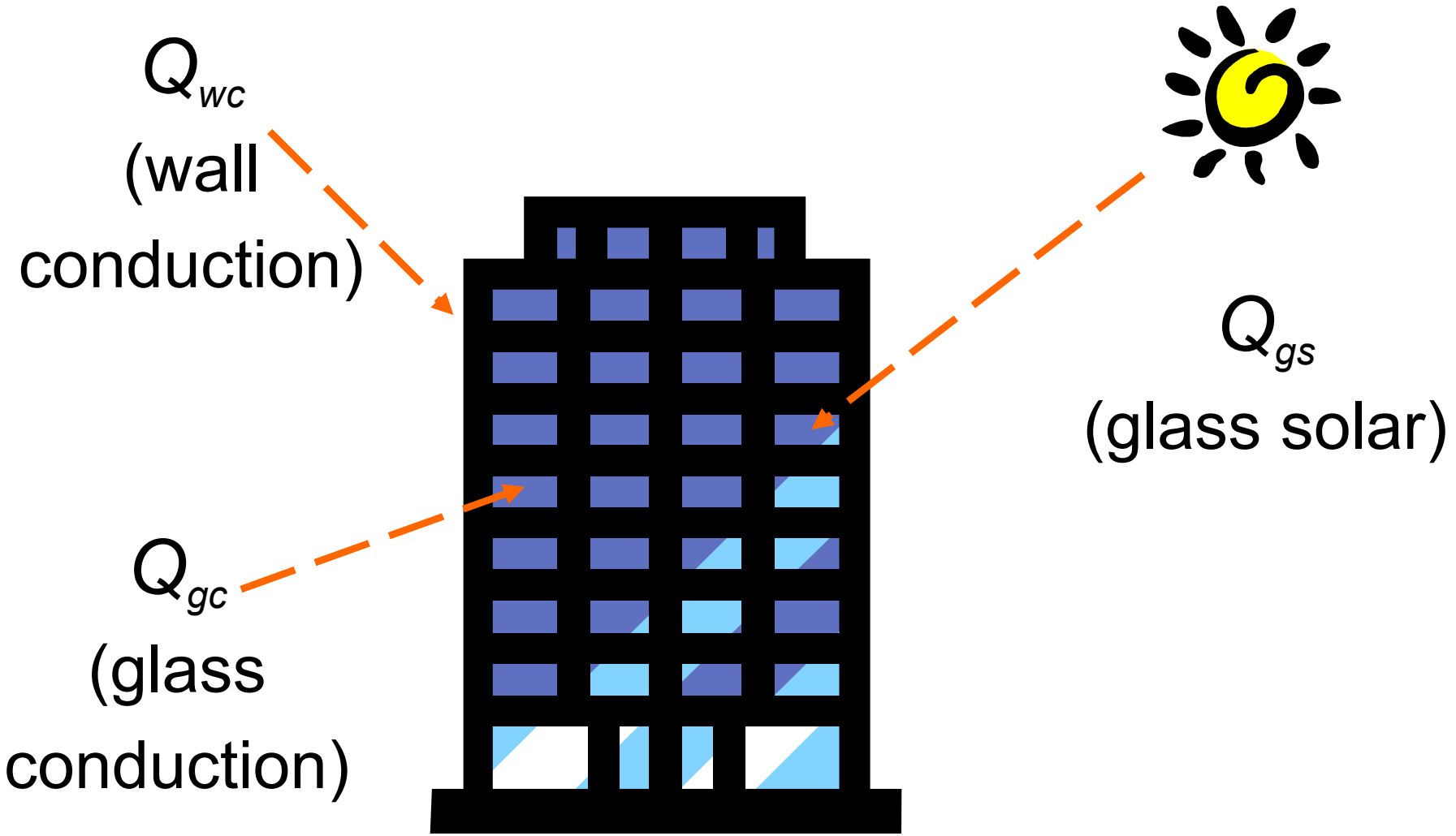
Building envelope



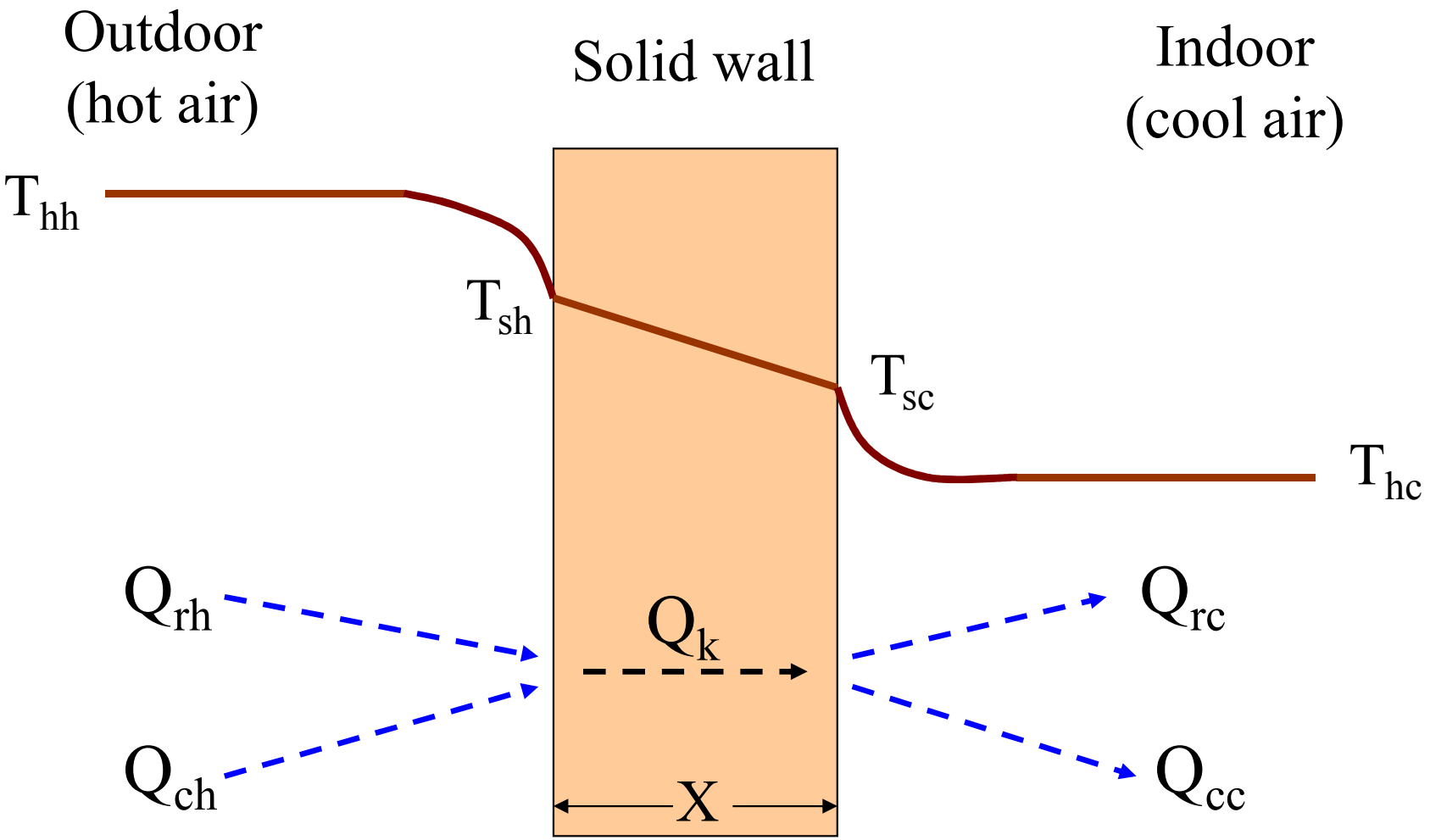
- Building envelope (or skin)
  - Walls, roofs, windows, skylights, etc.
    - Area, thermal properties, mass, shading
  - Good design
    - Consider & respond to local climate
    - Good thermal performance (insulation & control heat)
    - Appropriate window areas (view, daylight & heat)
    - Proper solar control (e.g. shading devices)
  - Need to balance with other requirements e.g. aesthetics and view (connect to outside)



Heat transmission through building envelope
(reduce heat flow/gain => reduce cooling energy)
(reduce heat loss in winter => reduce heating energy)



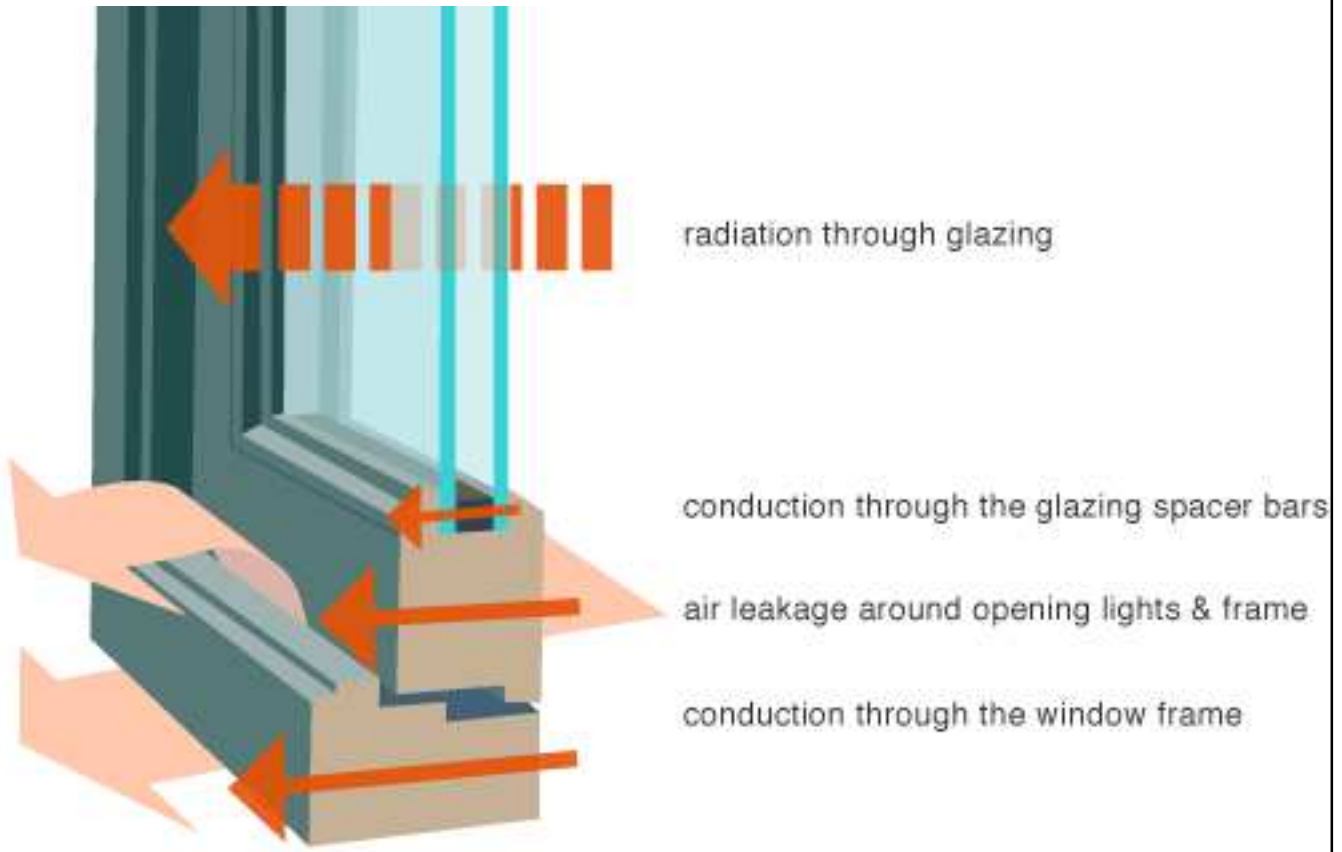
Thermal properties of building materials

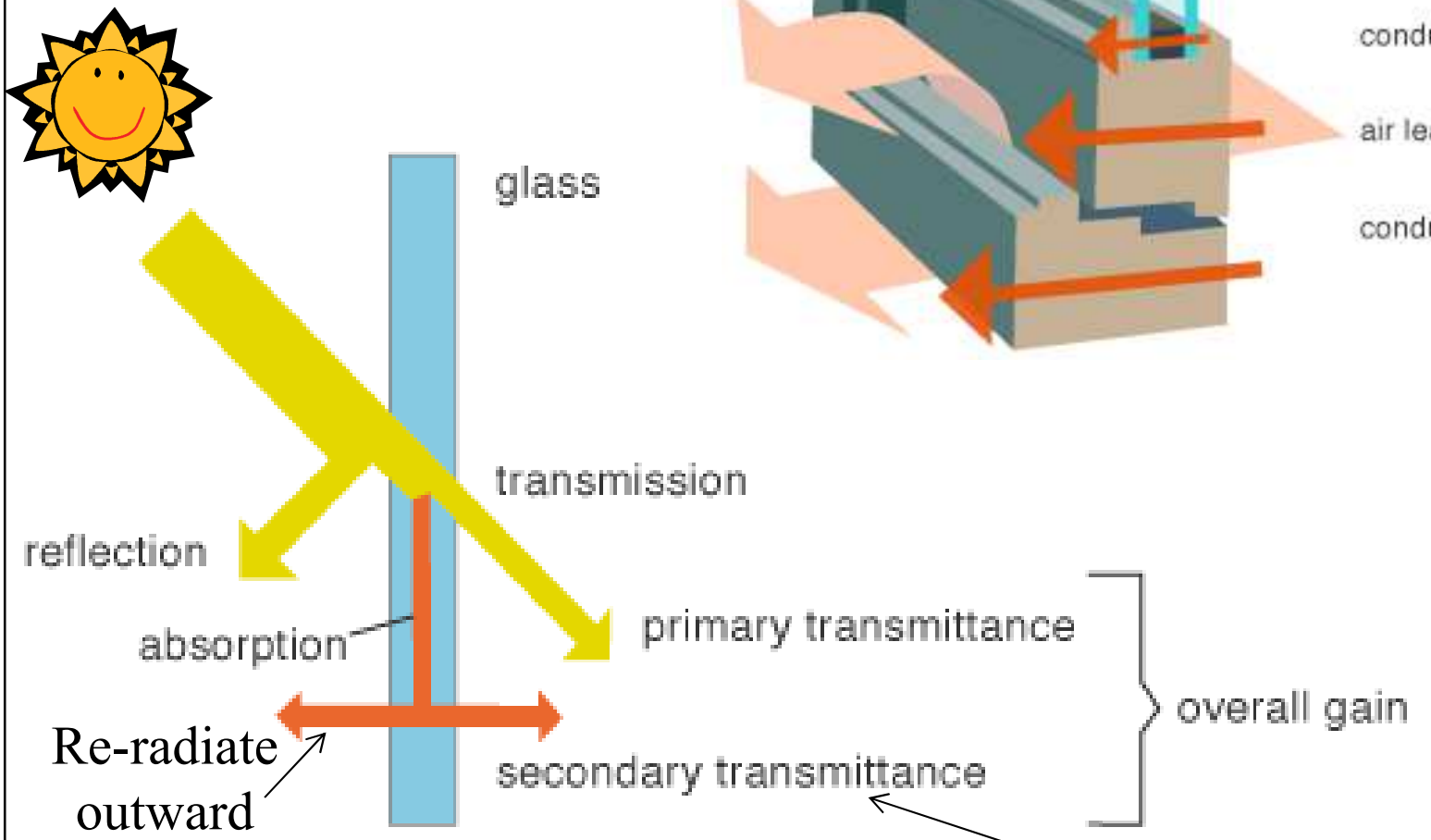


$$Q = A \cdot U \cdot \Delta T$$

Example: Q = (5 m x 4 m) x (2 W.m^{-2}.K^{-1}) x (32 ˚C - 25 ˚C) = 280 W

Solar heat gain and heat loss through window glass

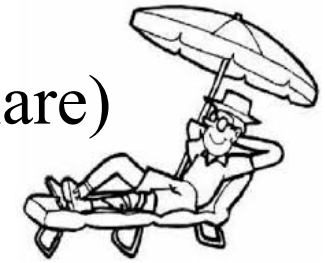


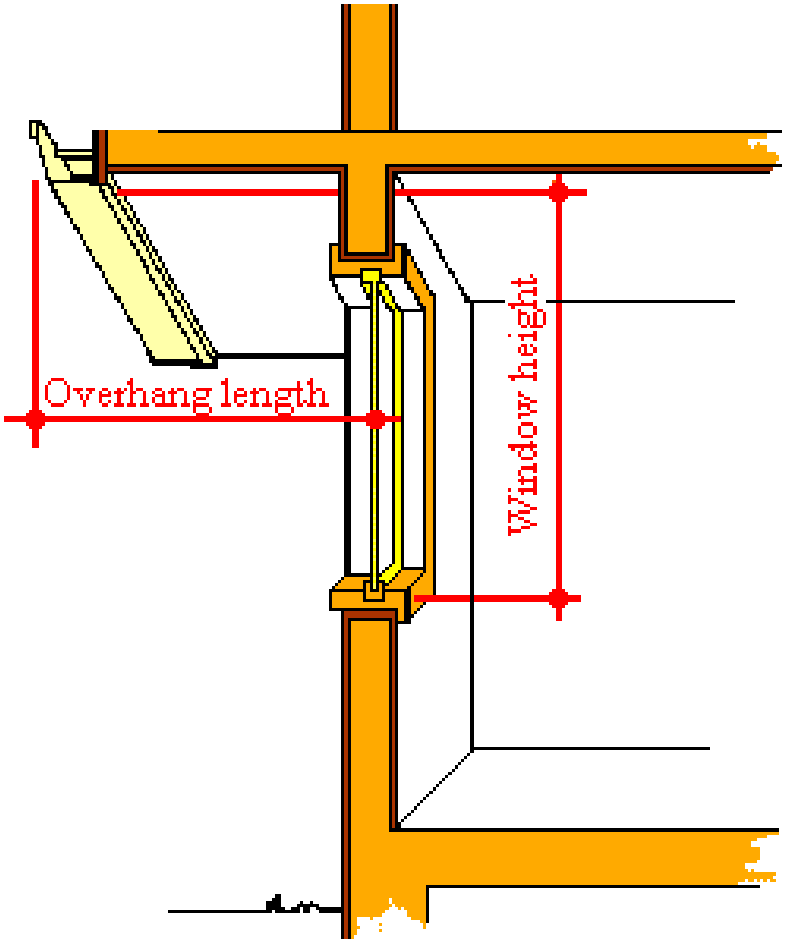


(Source: www.greenspec.co.uk/windows.php)

Shading devices (external and internal) for sun control

(reduce direct sun light => reduce cooling energy & glare)

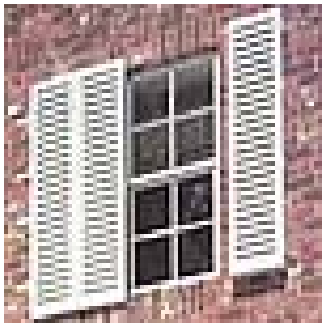




Overhang

Louvers

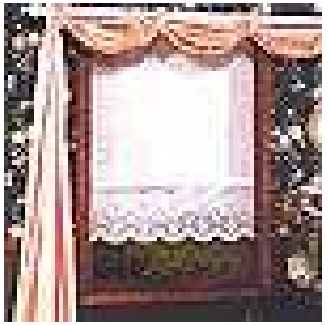
Awnings



Shutters

Drapes and curtains

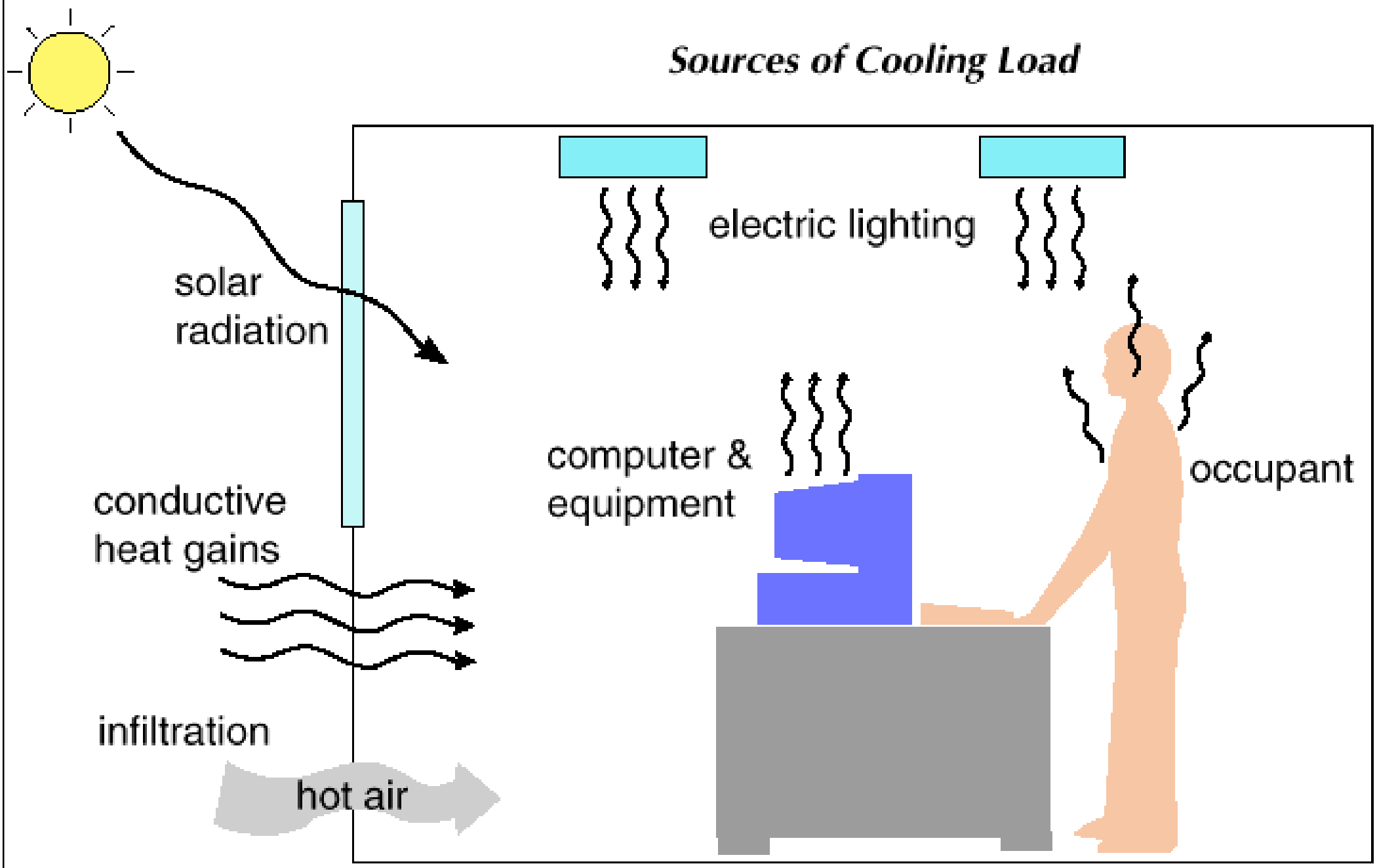
Venetian blinds



Roller shades

HVAC systems

- Heating, ventilating & air-conditioning (HVAC) systems
  - Usually the most important energy users
  - Provide for occupant comfort, health and safety
  - HVAC design is affected by architectural features and occupant needs
- In Hong Kong, heating load is small and main focus is on air-conditioning or cooling energy use

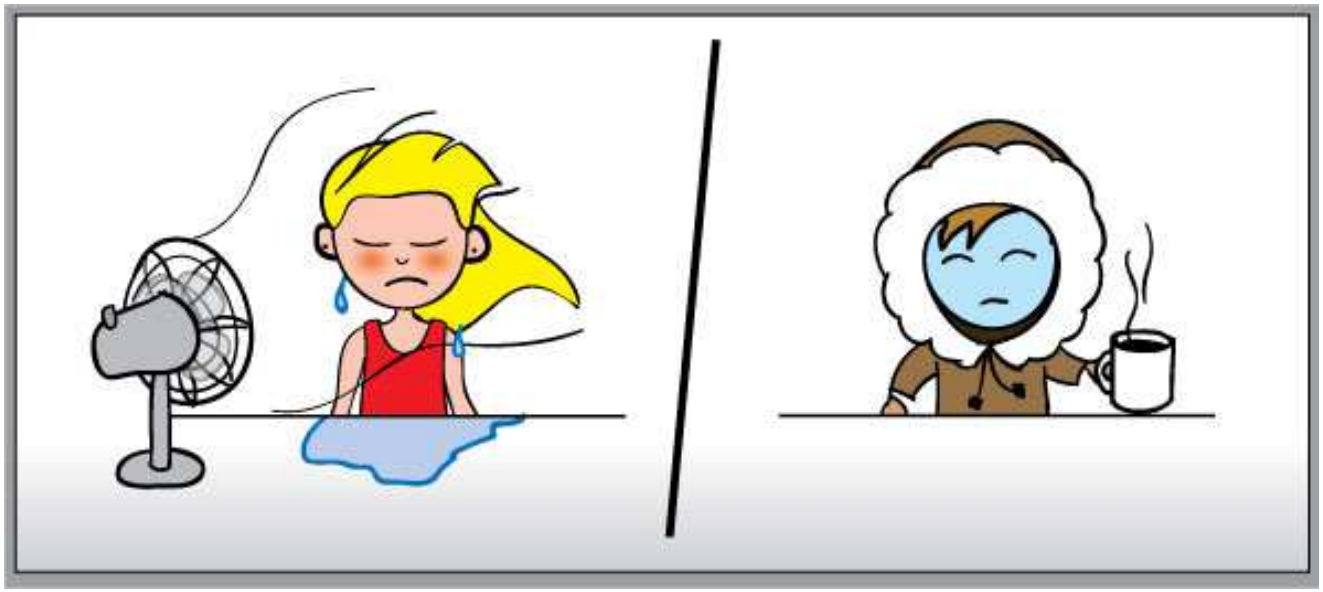

Sources of Cooling Load
electric lighting
solar
radiation
computer &
equipment
occupant
conductive
heat gains
infiltration
hot air

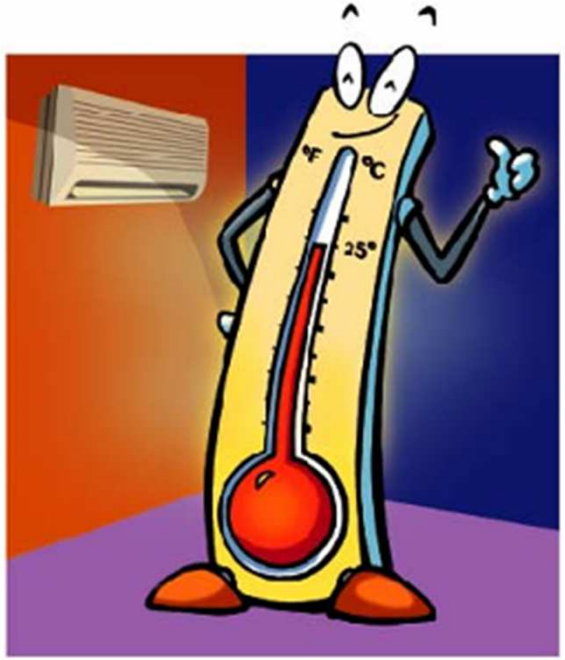
HVAC systems

- Strategies for achieving energy efficiency
  - Reduce heat load in the air-conditioned spaces
  - Promote natural cooling or ceiling fans, prior to using mechanical cooling
  - Adopt “relaxed dress code” and flexible work schedule, wherever possible
  - Ensure good house-keeping and user education
- Avoid wastage of energy by proper use of air-conditioning and suitable temperature setpoint

Japanese Energy Strategy: Hawaiian Shirts
"Super Cool Biz" campaign (dress casual can reduce cooling needs)

(Source: The Wall Street Journal, http://online.wsj.com)





Just nice at 25°C

Electricity Efficiency Centre

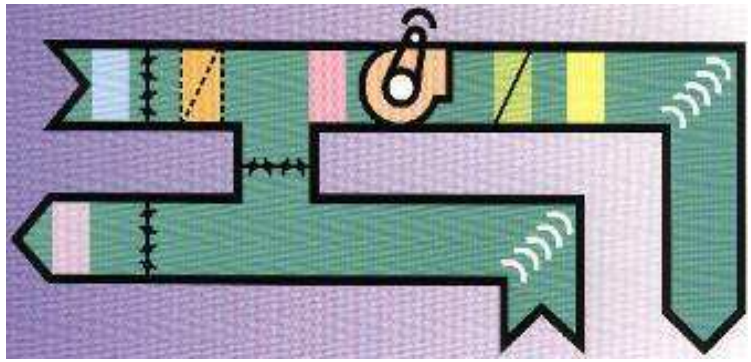
Cleaner filter filters better.

Electricity Efficiency Centre

HVAC systems

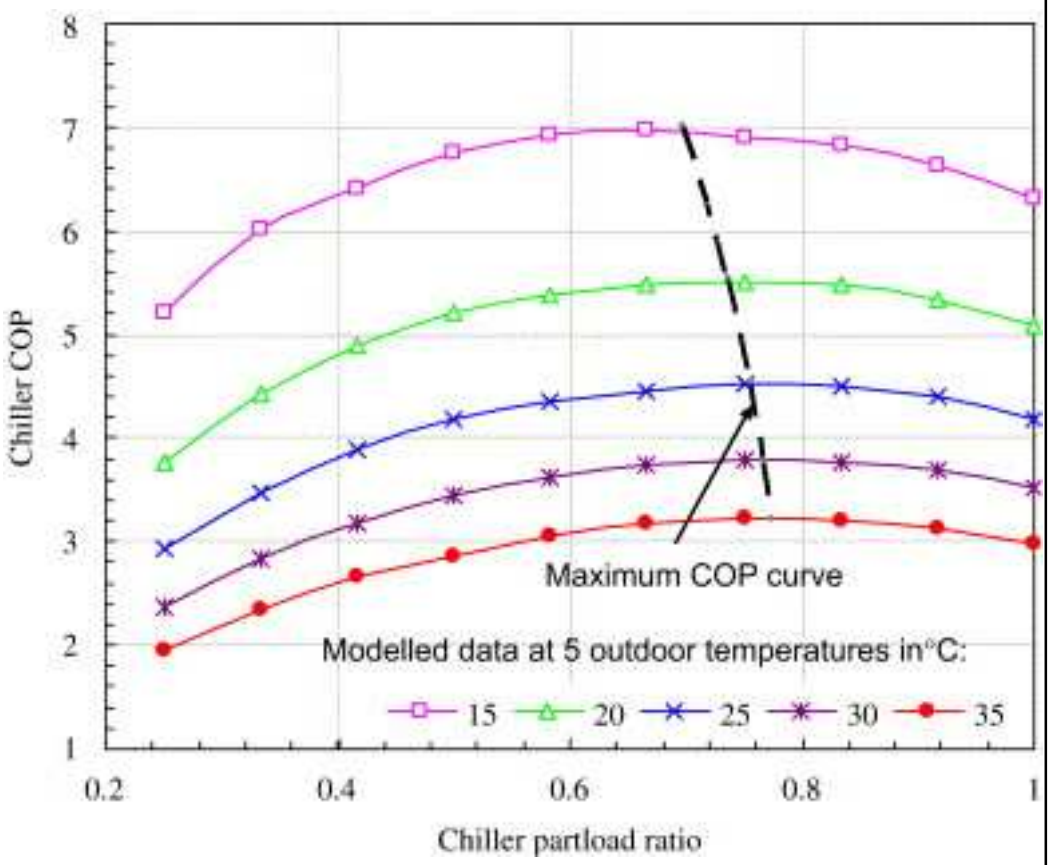
- HVAC system design and operation
  - System characteristics
    - Type of systems
    - Energy efficiency ratios (EER)
    - Coefficient of performance (COP)
    - System operation & control
  - Equipment and plant operation
    - Especially during partload conditions (most of the time)
    - Opportunity for heat recovery
    - District cooling or energy system

Improve partload efficiency of HVAC equipment and plant



HVAC system and plant

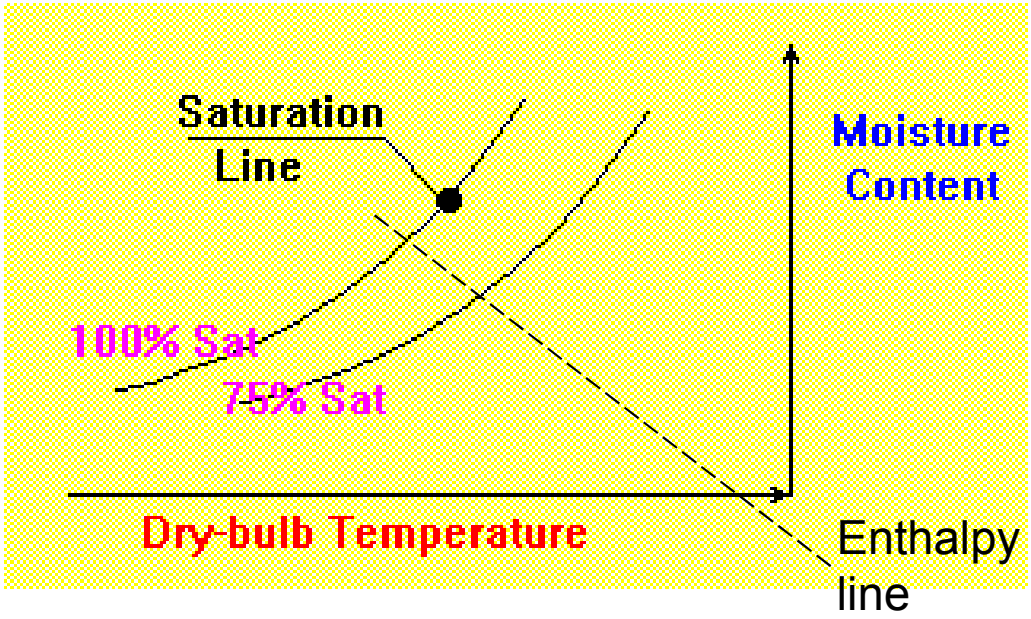
Highest efficiency at about
70%-90% partload ratio



Chiller partload ratio

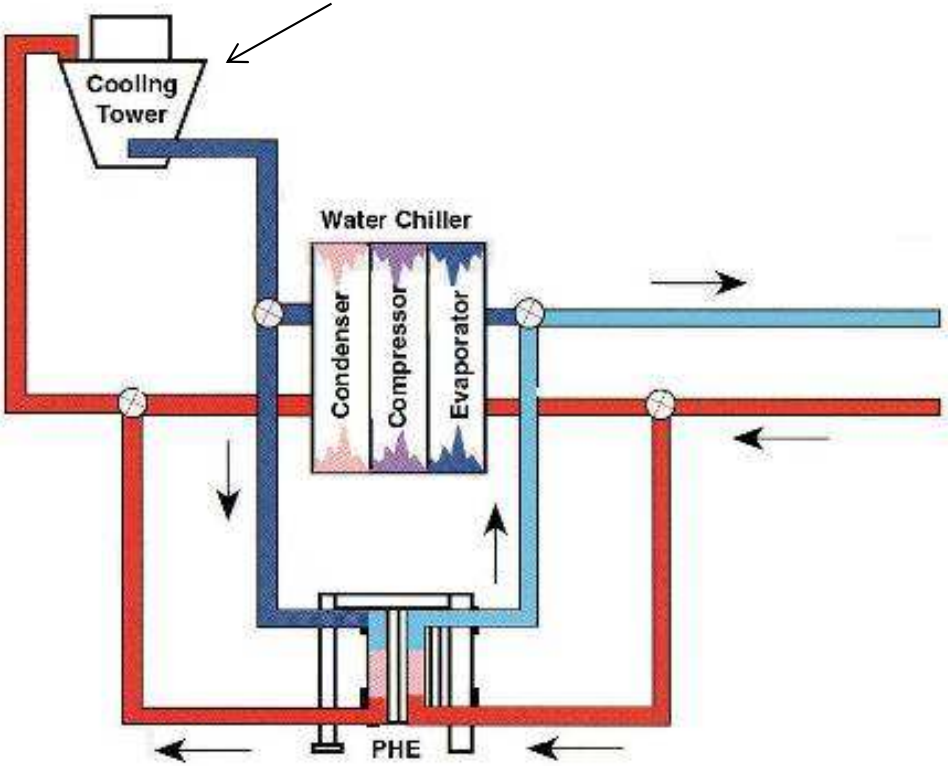
‘Free’ cooling methods in HVAC systems

Analyse the outdoor air conditions on a psychrometric chart



(a) Air-side economiser cycle
- intake more outdoor air when its enthalpy (energy content) is lower than indoor air

Use cooling tower alone to produce chilled water (chiller turned off)

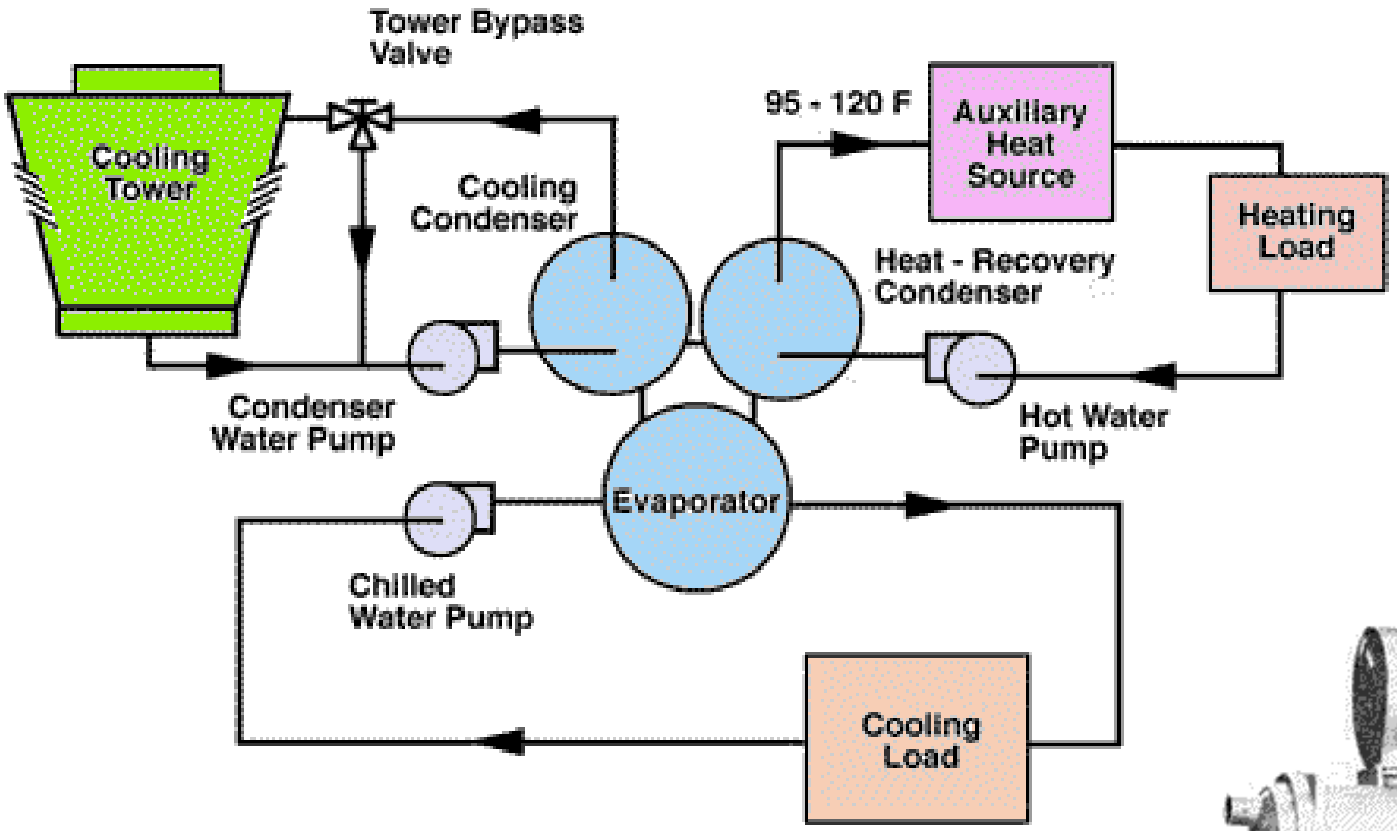


(b) ‘Free’ refrigeration
- chiller bypass when the system can be cooled by ambient

(*See also: http://en.wikipedia.org/wiki/Free_cooling)

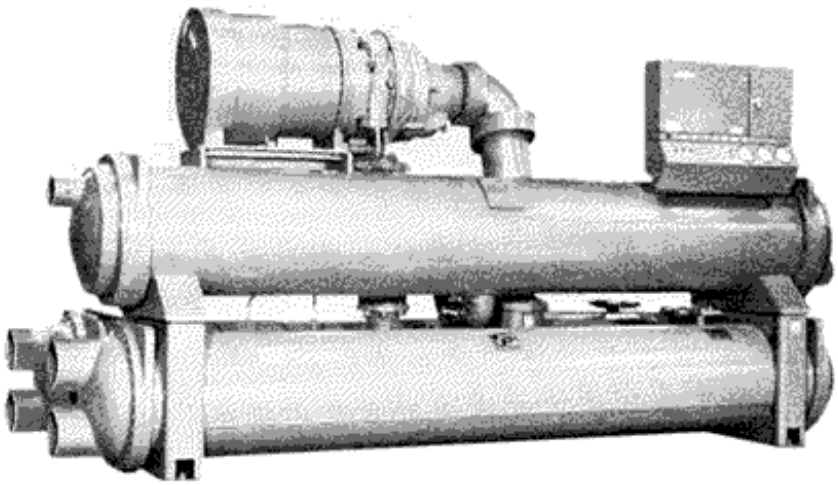
Waste heat recovery – e.g. double bundle heat recovery chiller

Strategy: use of heat recovery



Make use of waste heat from condenser to produce warm/hot water or for heating the space.

- Waste heat = “dumped” heat that can still be reused
- Waste heat recovery saves fuel

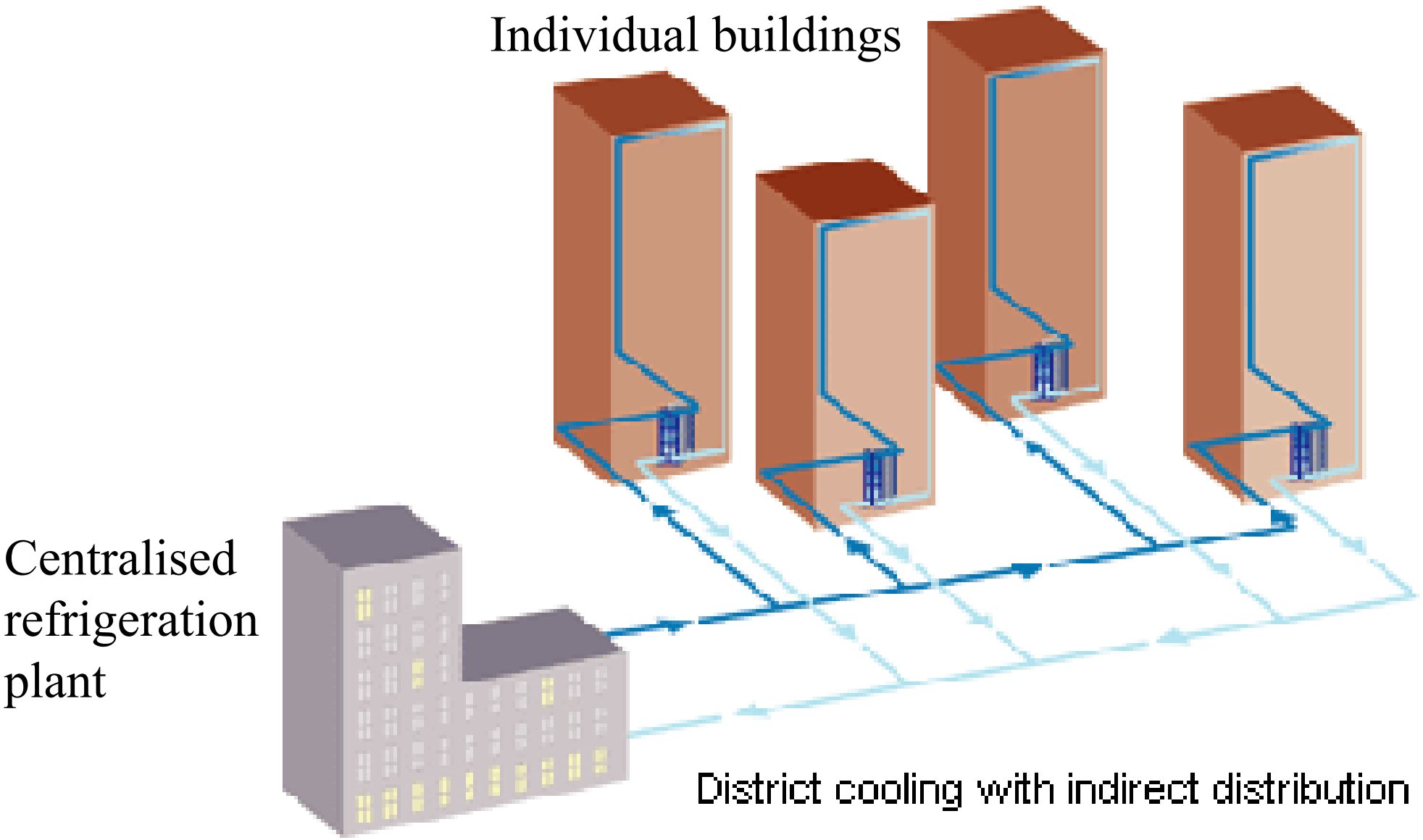


Double bundle heat recovery chiller

(*See also: http://www.energyefficiencyasia.org/energyequipment/ee_ts_wasteheatrecovery.html)

District cooling system (DCS)

Strategy: total energy approach

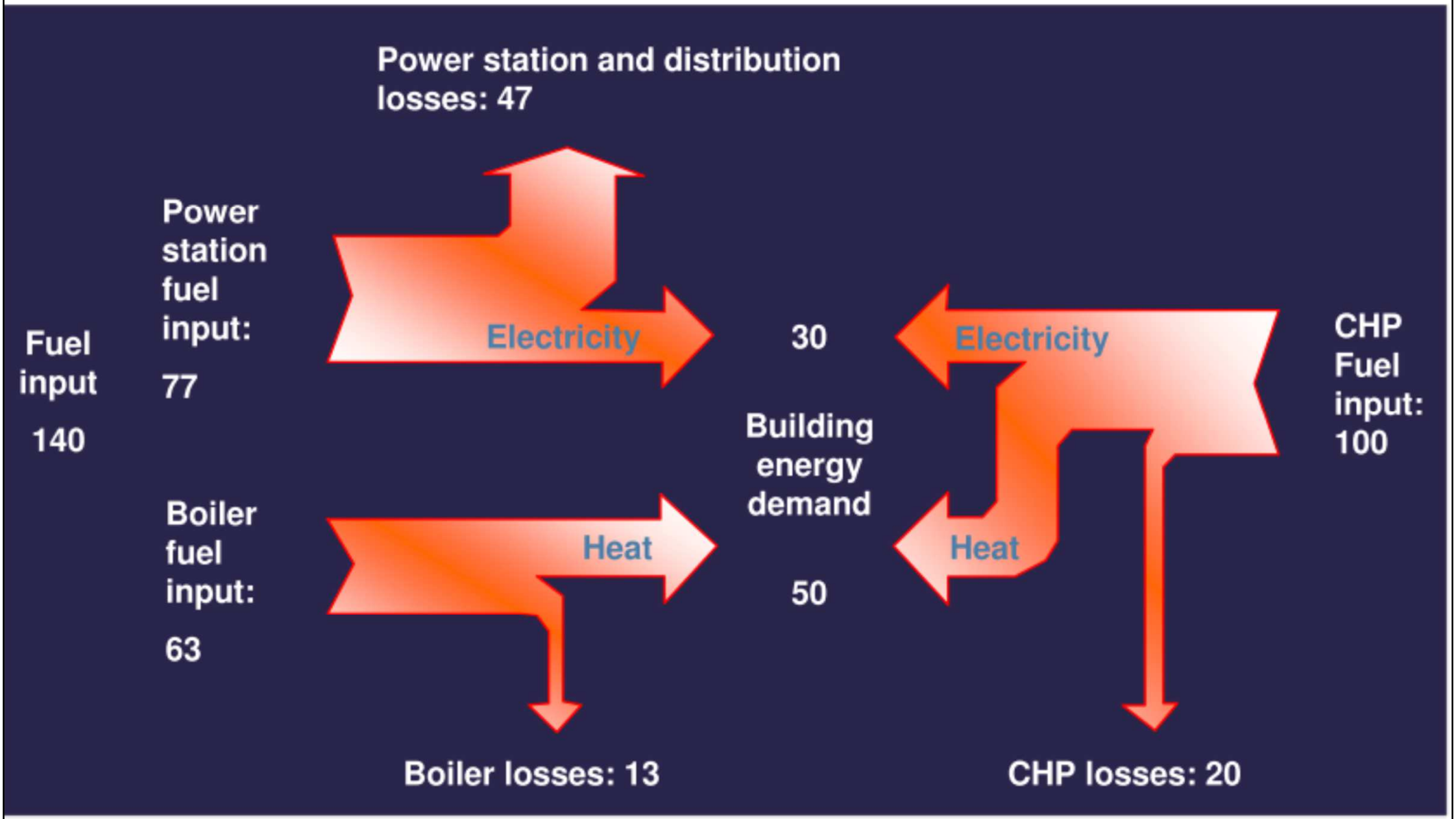


>> Do you know what are the advantages of DCS?

(*See also: http://www.energyland.emsd.gov.hk/en/building/district_cooling_sys/)

(Video: District Cooling System (5:58) http://www.youtube.com/watch?v=DDY32Chx6Gg)

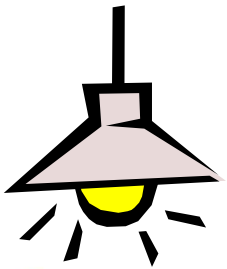
Combined heat and power (CHP), also known as cogeneration, reduces energy use by 30%



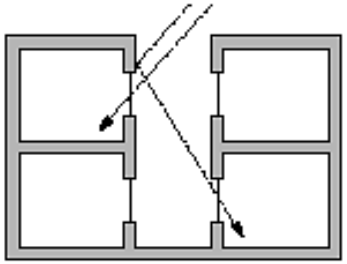
Further information: http://en.wikipedia.org/wiki/Cogeneration

(Source: www.revival-eu.net)

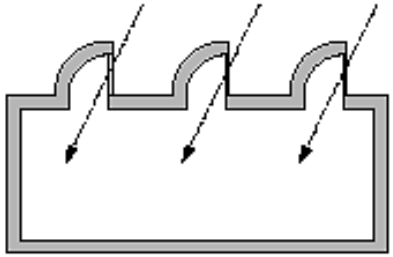
Lighting systems



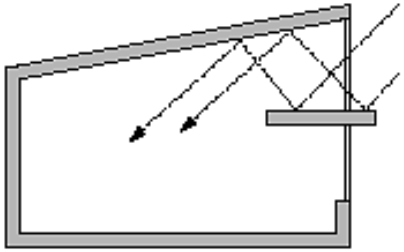
- Energy efficient lighting design strategies:
  - 1. Promotion of natural daylighting
  - 2. Use of energy efficient lamps and luminaires
  - 3. Switching and control of artificial light
  - 4. Combination of general and task lighting
  - 5. Electric lighting integrated with daylight
  - 6. Proper room surfaces and space design



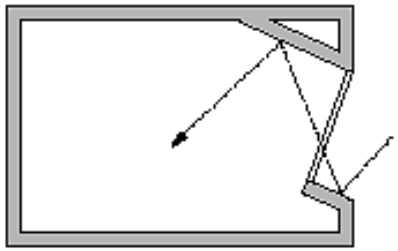
Light well



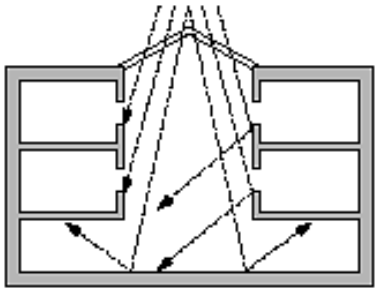
Roof monitor



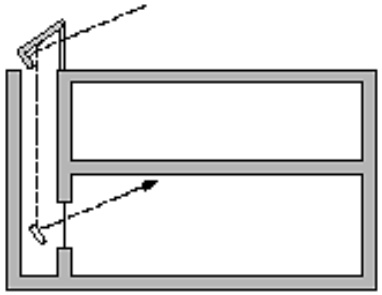
Light shelf



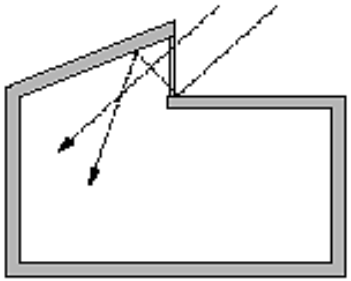
External reflectors



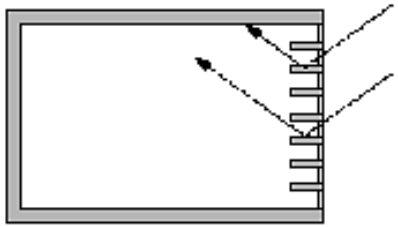
Atrium



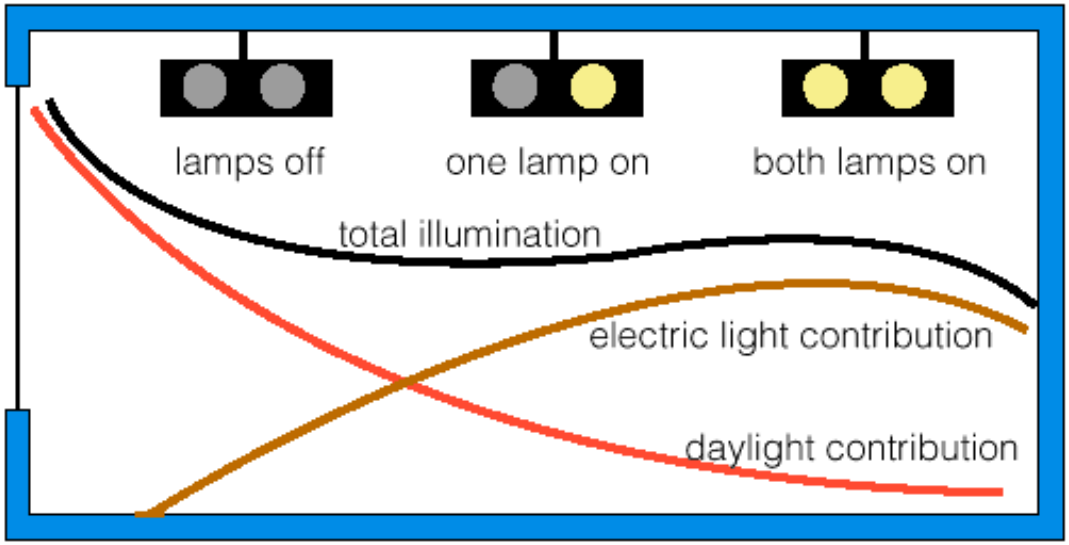
Light duct



Clerestory

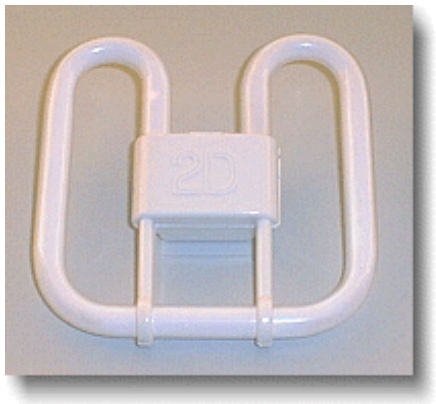


Reflective blinds

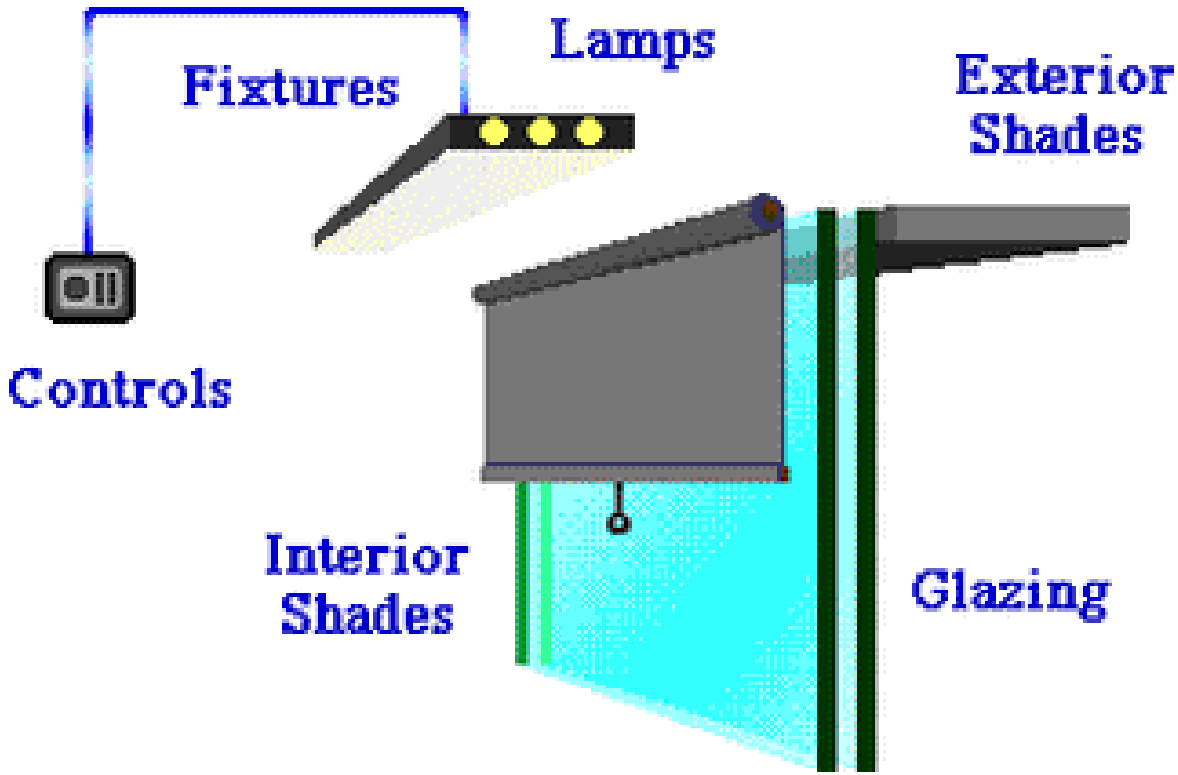


Daylighting design and control

Energy efficient lighting design strategies

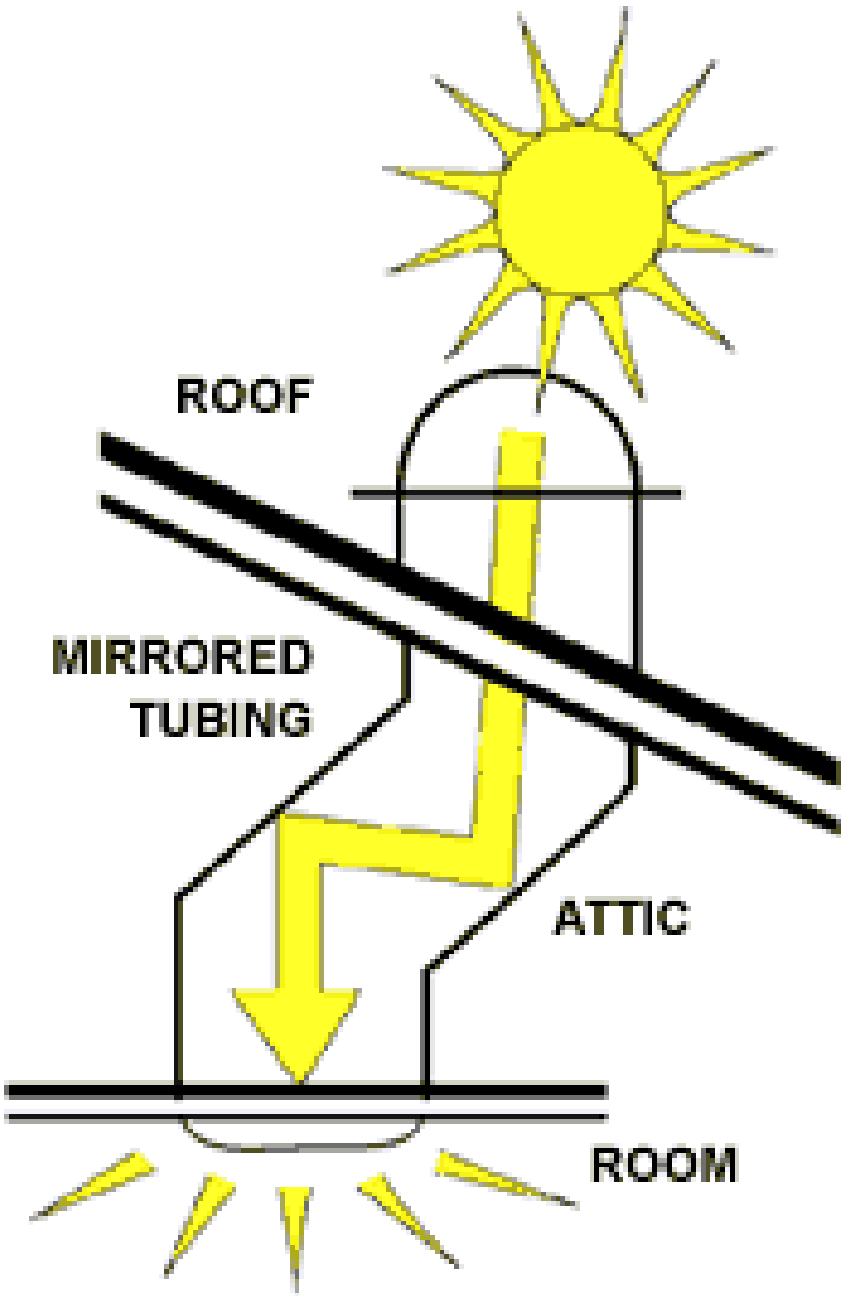


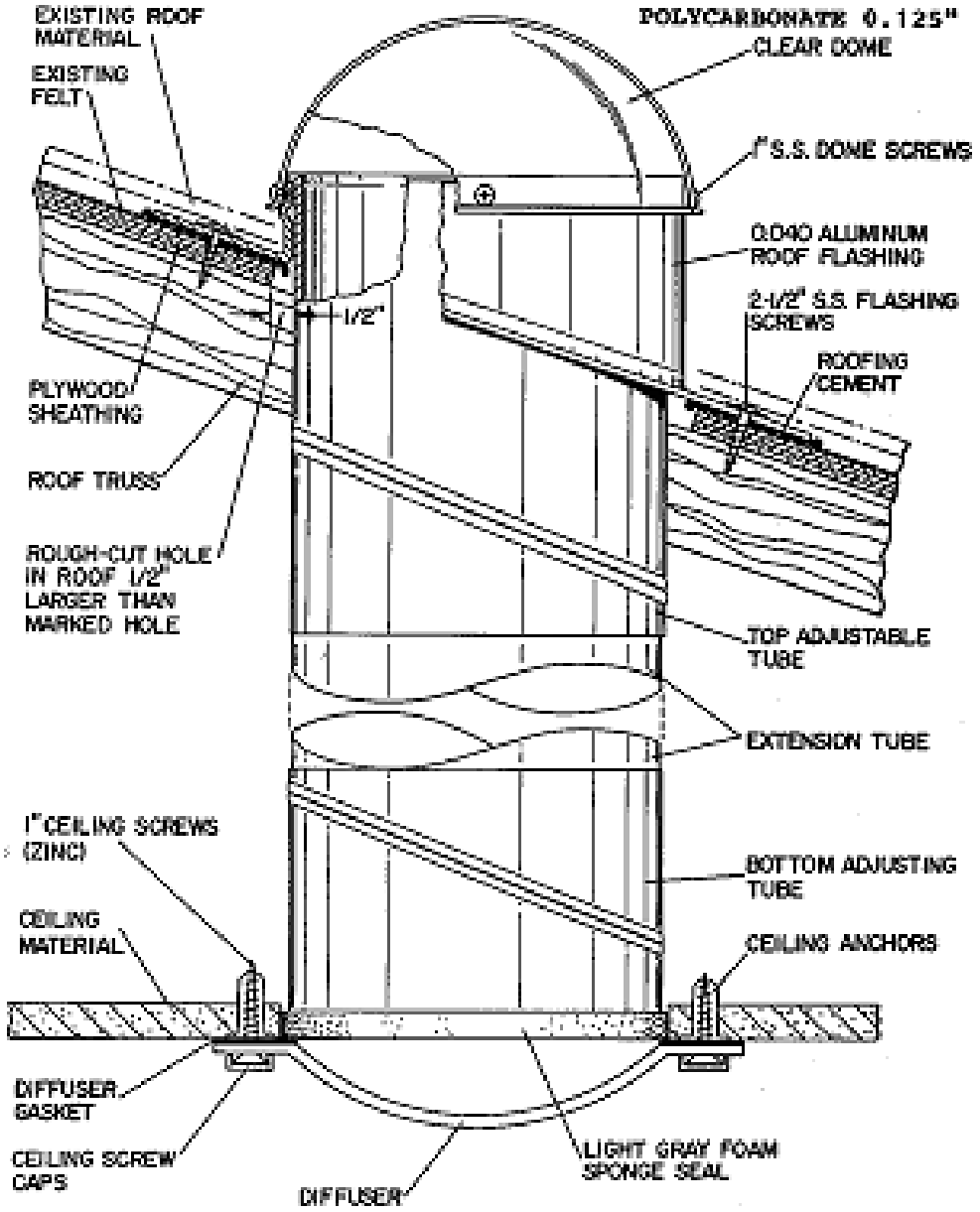
Energy efficient fittings (e.g. compact fluorescent lamps)



Lighting controls and interactions with windows

Light tube system

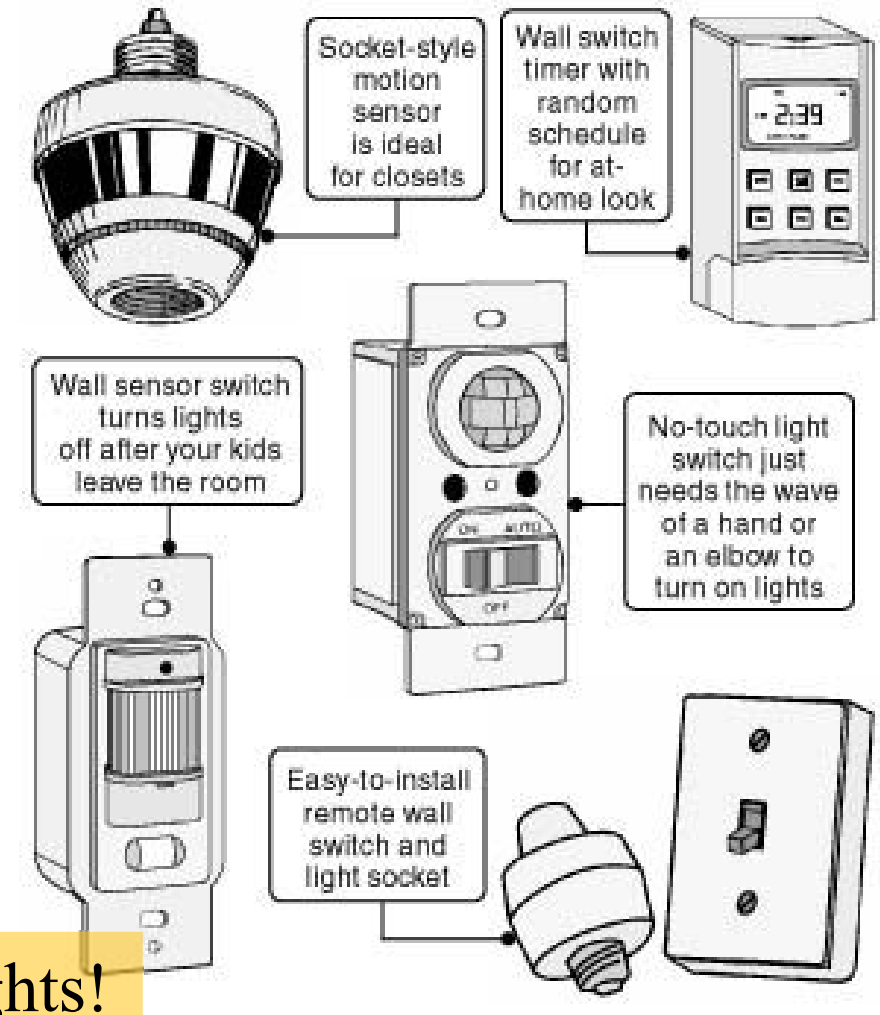




This can help to direct daylight into building interior

Lighting systems

- Typical lighting controls
  - Switches
  - Occupancy sensing
  - Scheduling (timeclocks)
  - Daylight dimming
  - Tuning
  - Preset dimming
  - Building management

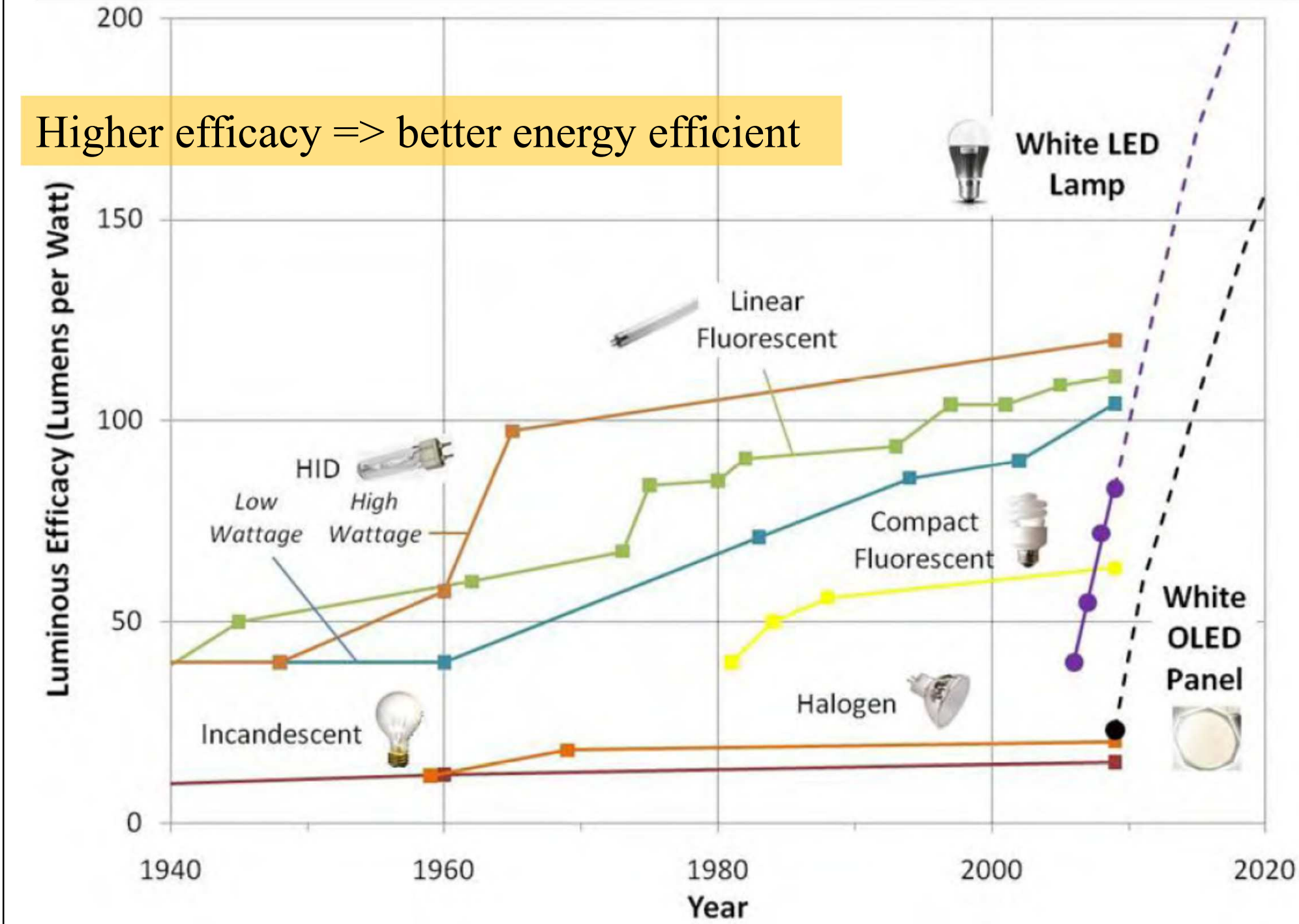


Remember: switch off unnecessary lights!

Which ones are more energy efficient?

Various light sources for general lighting

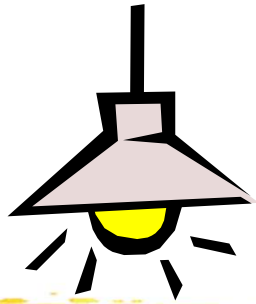
(Source: Advanced Lighting Guidelines 2001)



Historical and predicted efficacy of light sources

(Source: US Department of Energy)

Lighting systems



- Video: Energy 101: Light Bulbs (4:47)

  - http://youtu.be/Pk60-D61h34
  - Our animated correspondent, 'Little Lee Patrick Sullivan,' kicks off our "Energy 101" series with an inside look -- literally -- at light bulb technology. He goes inside an incandescent, a compact fluorescent and an LED bulb to see what makes them work, and their potential drawbacks.

Evolution of light bulbs

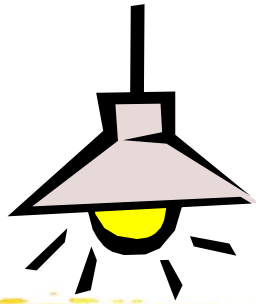
Edison lamp

Incandescent lamp

Compact fluorescent lamp

LED lamp

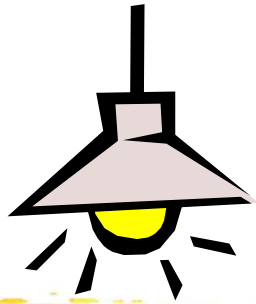
Lighting systems



- Light emitting diode (LED)
  - Advantages
    - Low power consumption
    - Long lasting (long useful life)
    - Durable (withstand impact & vibration)
    - Cool (little heat produced)
    - Modular design & compact size
    - Controllability (colour balance & intensity)
    - Instant on, frequent switching
    - No annoying flicker
    - Low cost of manufacture
    - No ultraviolet & infrared radiation
    - Mercury free
  - Disadvantages
    - Focused, directional light
    - Need different optics design
    - May need heat sink (thermal management)

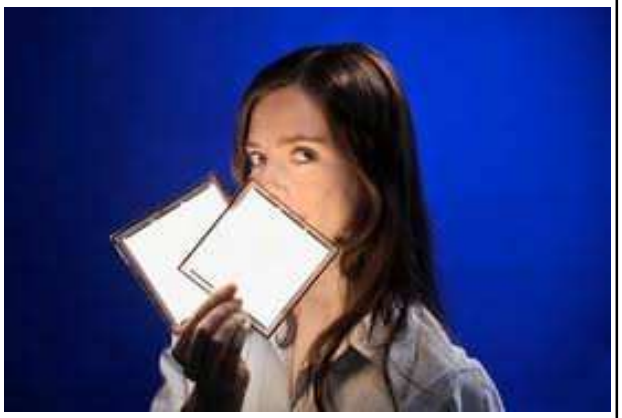
LED candles

Lighting systems



- Solid state lighting (SSL)
  - Emits light from semi-conductor (solid)
    - Light emitting diode (LED)
    - Organic light-emitting diodes (OLED)
    - Polymer light-emitting diodes (PLED)

Good potential for future lighting



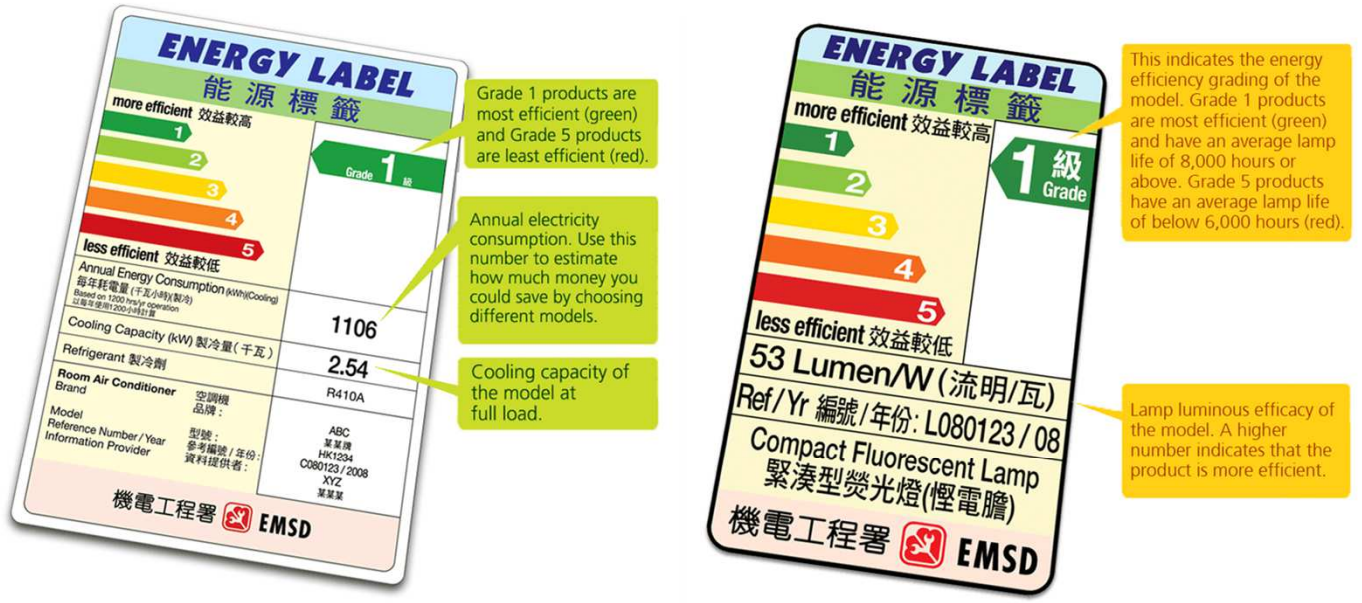
  - Advantages:
    - Low power consumption
    - Reduced heat generation
    - Greater resistance to shock, vibration, and wear

Other considerations

- Other building services systems
  - Electrical installation
  - Lifts and escalators
  - Water supply systems
  - Town gas supply system (cooking)

- Basic principle for energy efficiency:
  - Energy efficient appliances, correct sizing, design and operation, effective distribution network and proper maintenance

Energy efficiency labels in HK



Examples of mandatory energy efficiency labels in Hong Kong

Examples of voluntary energy efficiency labels in Hong Kong

(Source: www.energylabel.emsd.gov.hk)

Other considerations

"0"

- Zero energy building (ZEB)
  - A building that produces as much energy on-site as it consumes on an annual basis
  - "Net" zero energy building
- Advantages of ZEB:
  - Reduce energy consumption and costs
  - Reduce carbon emissions
  - Reduce dependence on fossil fuels

(*See also: Zero Carbon Building in HK, http://zcb.hkcic.org)

Other considerations

- Video: Achieving Net-Zero-Energy Buildings - ASHRAE (2:05)
  - http://youtu.be/pQFJr5E7_R0
  - By American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)
  - 1. Building envelope measures
  - 2. HVAC, service water heating and lighting measures
  - 3. Renewable energy measures