PolyU Department of Building Services Engineering
14 March 2009

Technical Talks for Design Project I & II (2008-2009)

Energy Efficiency in Buildings

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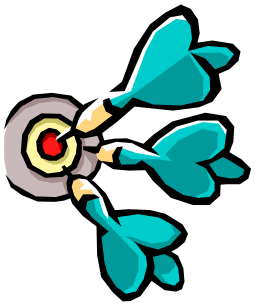
About the Speaker



- ***Dr. Sam C M Hui***
  - PhD, BEng(Hons), CEng, CEM, MASHRAE, MCIBSE, MHKIE, MIESNA, LifeMAEE, AssocAIA

CEng = Chartered Engineer

CEM = Certified Energy Manager

LifeMAEE = Life Member, Association of Energy Engineers

  - Worked in 1998 as a visiting researcher in the Asia Pacific Energy Research Centre, Japan
  - Research interests: energy efficiency in buildings and sustainable building technologies

Contents

- Energy Basics
- Energy Use in Buildings
- Energy Efficiency
- Energy Policy and Codes

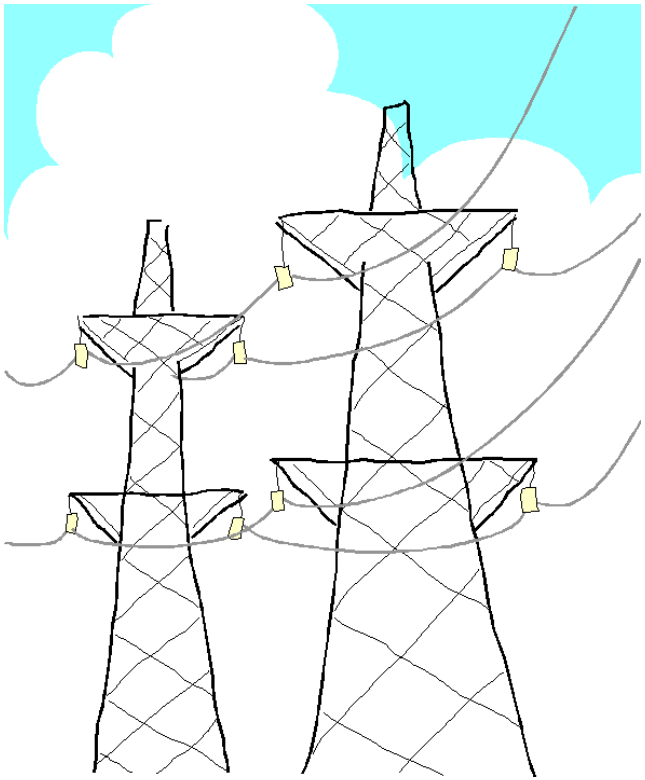
Energy Basics

- Units of energy
  - Kilowatt-hour (kWh), 1 kWh = 3.6×10^6 joule
    - 1 kWh = 3.6 MJ = 860 kcal = 3412 Btu
  - Calorie (卡路里), 1 calorie (cal) = 4.2×10^3 J
  - British thermal unit (Btu), 1 Btu = 1.055×10^3 J
  - Therme (gas supply), 1 therme = 100 000 Btu
  - Tonne of oil equivalent (toe) (from oil industry)
    - 1 toe = 4.2×10^{10} J = 42 GJ or 11.63 MWh or 10^7 cal
- Power unit:
  - 1 W = 1 J/s = 0.86 kcal/h = 3.41 Btu/h

Energy Basics

- Forms of energy: (*Supply side, primary energy*)
  - **Electricity** (most important)
  - Natural gas, town gas, liquified petroleum gas (LPG)
  - Oil products
  - Coal
  - Hydropower
  - Renewable energy (e.g. solar, wind)
  - Nuclear energy

能源



Energy Basics

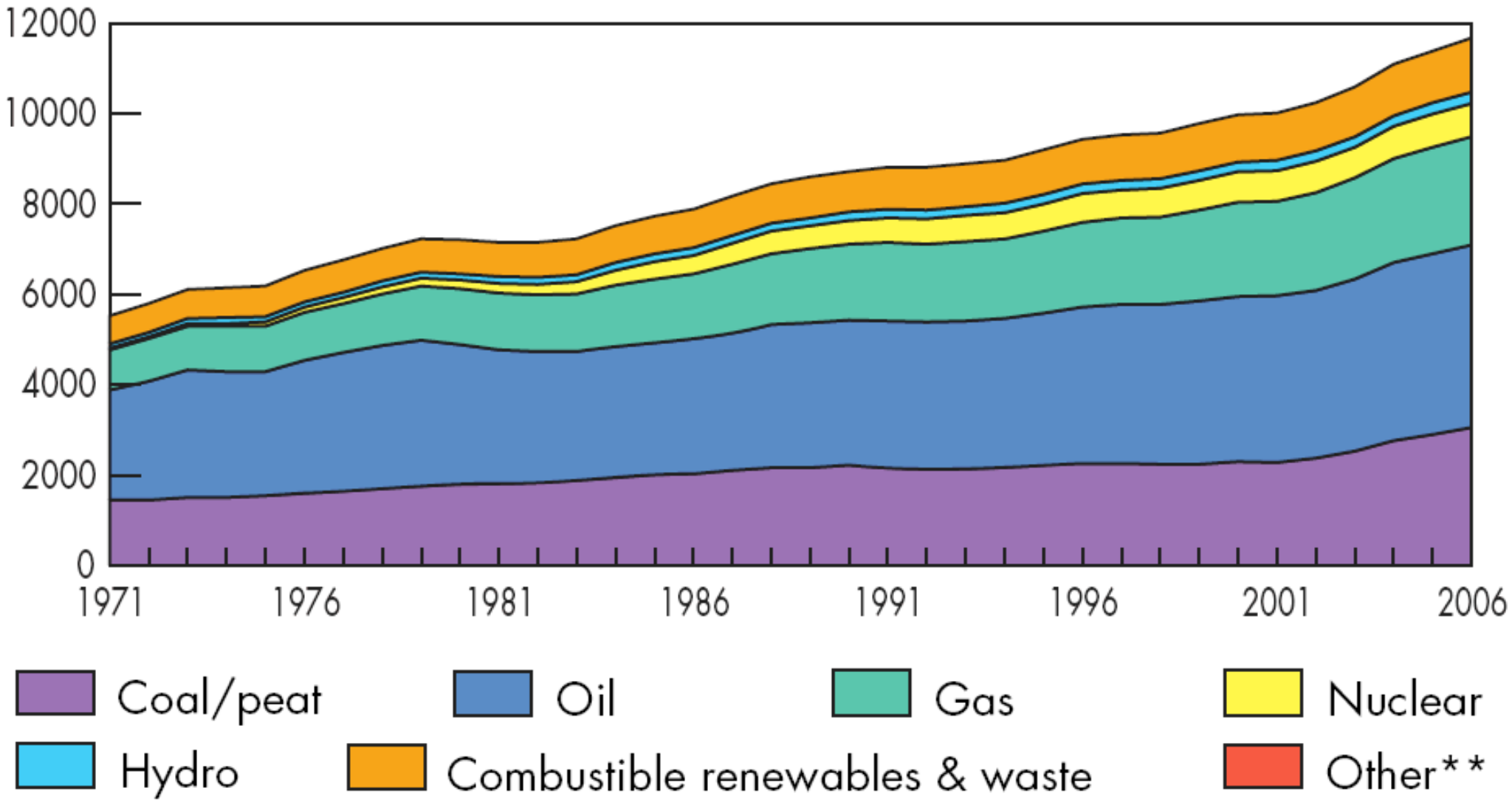
- Energy end-use: (*Demand side, final energy*)
  - Air-conditioning and ventilation
  - Lighting
  - Equipment
  - Hot water
  - Cooking
  - Industrial processes
  - Transportation

Energy Basics

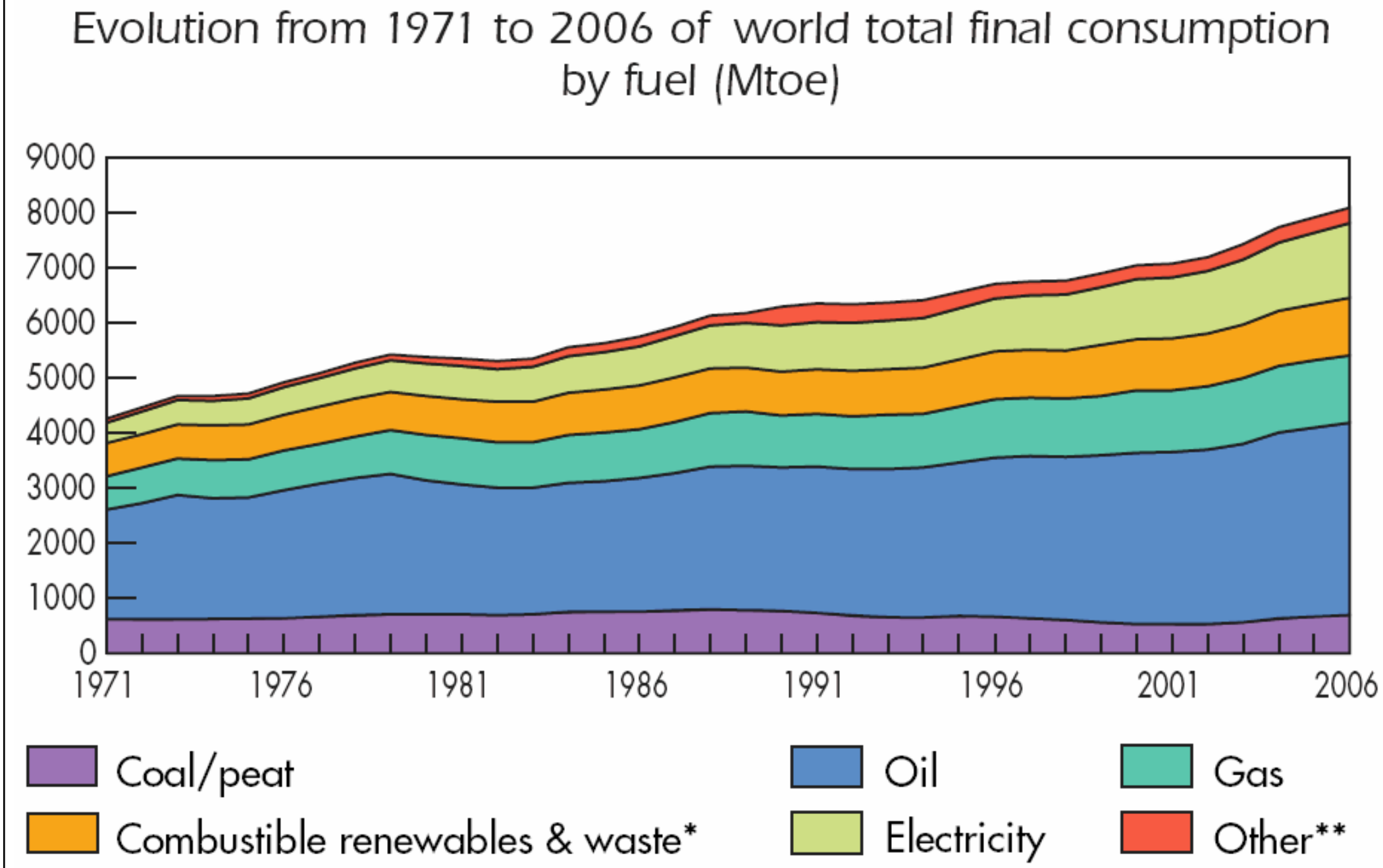
- **Energy** is important to every society
  - Economic, environmental & social impacts
  - It is also a key issue for ***sustainable development***
- Use energy …
  - Consume finite fossil fuels (oil, coal, natural gas)
  - Cause air pollution & environmental damage
  - Contribute to global warming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

(TPES)

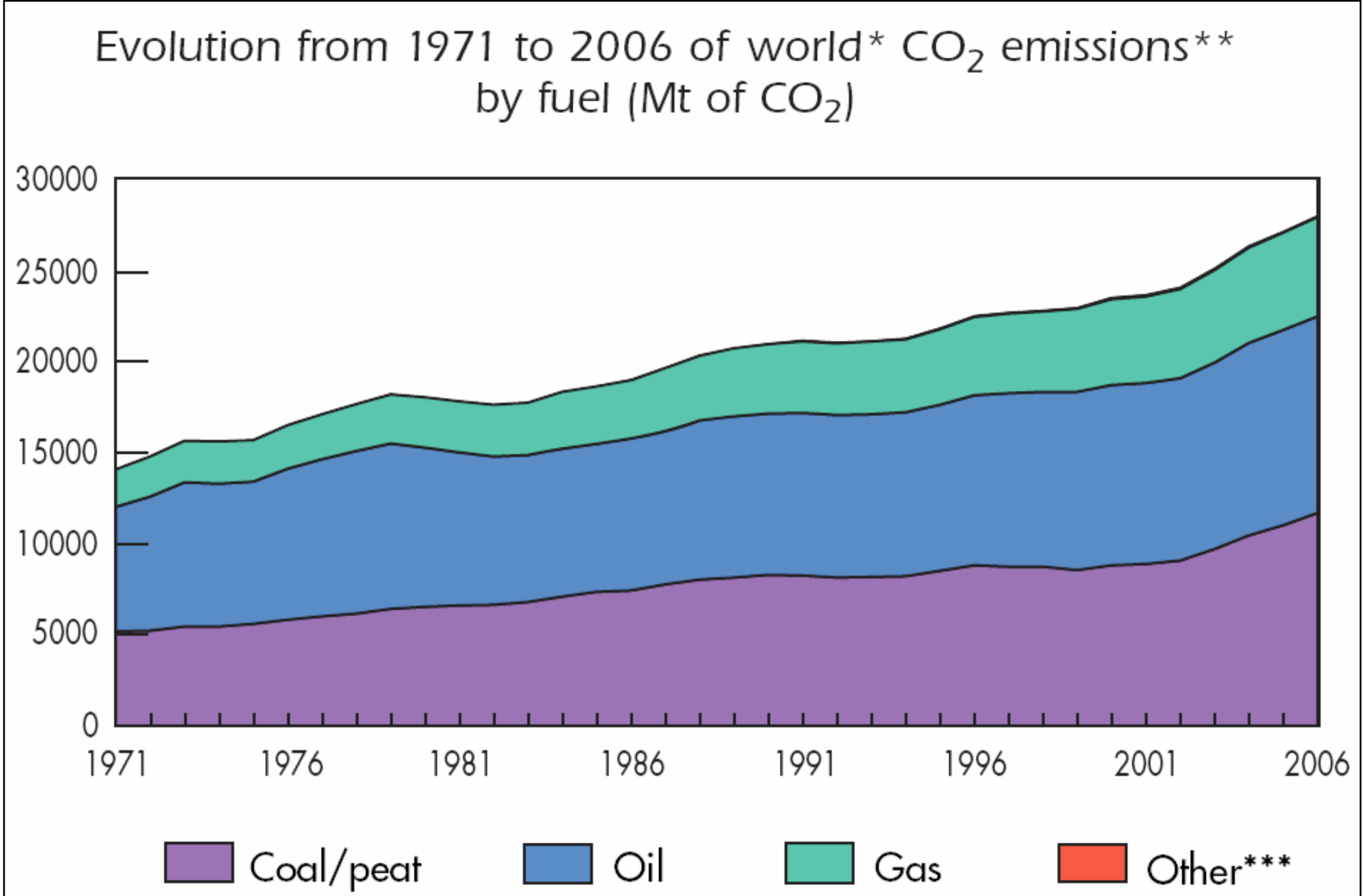
Evolution from 1971 to 2006 of world total primary energy supply* by fuel (Mtoe)



(* Source: IEA, 2008. *Key World Energy Statistics 2008*, International Energy Agency, Paris. Available at www.iea.org)



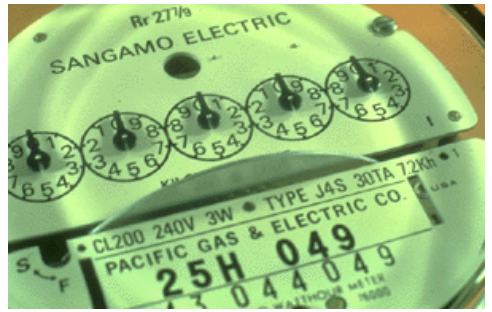
(* Source: IEA, 2008. *Key World Energy Statistics 2008*, International Energy Agency, Paris. Available at www.iea.org)



(* Source: IEA, 2008. *Key World Energy Statistics 2008*, International Energy Agency, Paris. Available at www.iea.org)

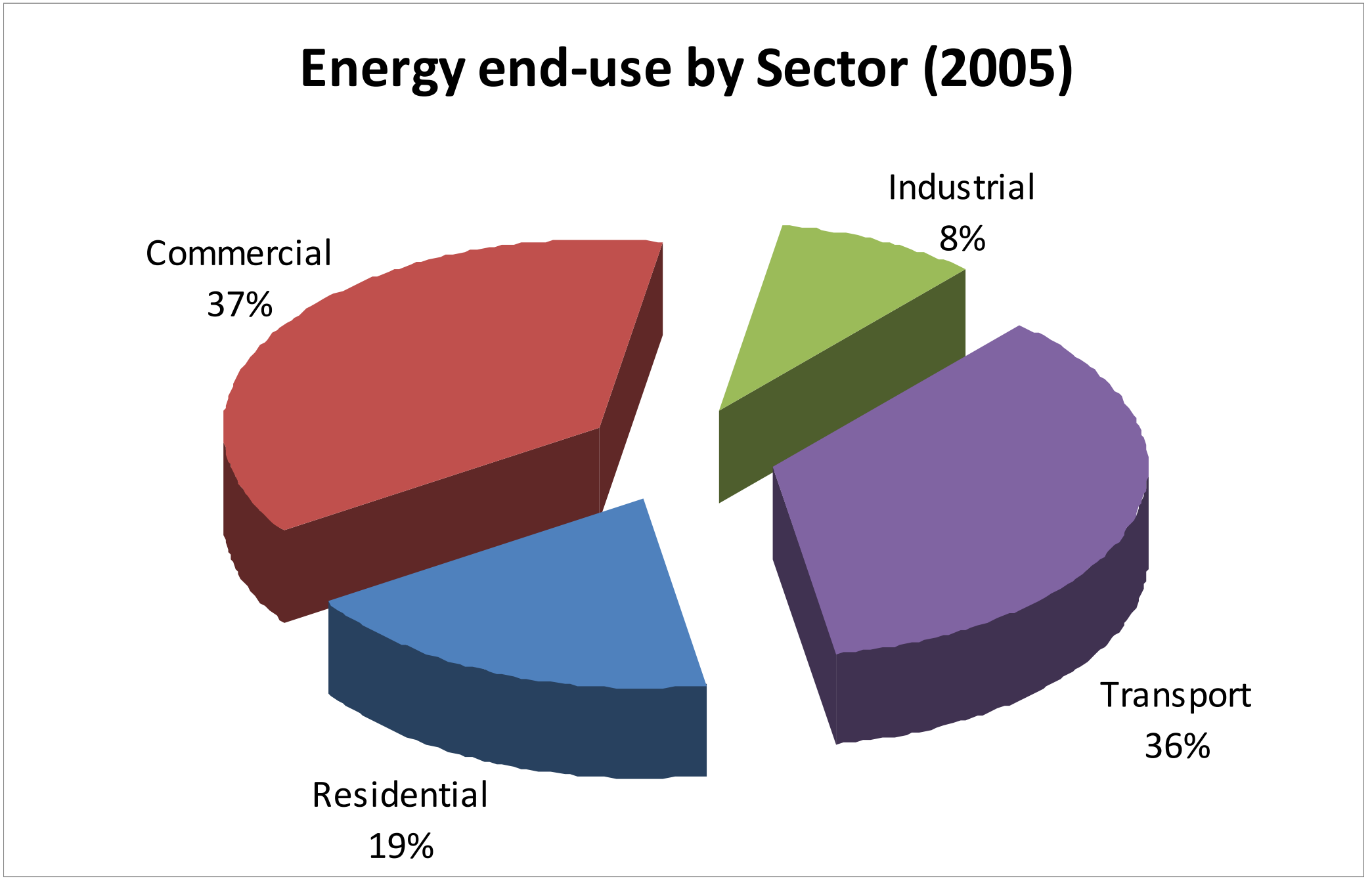
Energy Basics

- Significance of energy efficiency
  - Economics
    - Energy costs and operating costs
  - Energy security
    - Energy supply (political and economic reasons)
  - Environment
    - Climate change, global warming, air pollution
  - Resources depletion
    - Oil, gas and coal will be used up

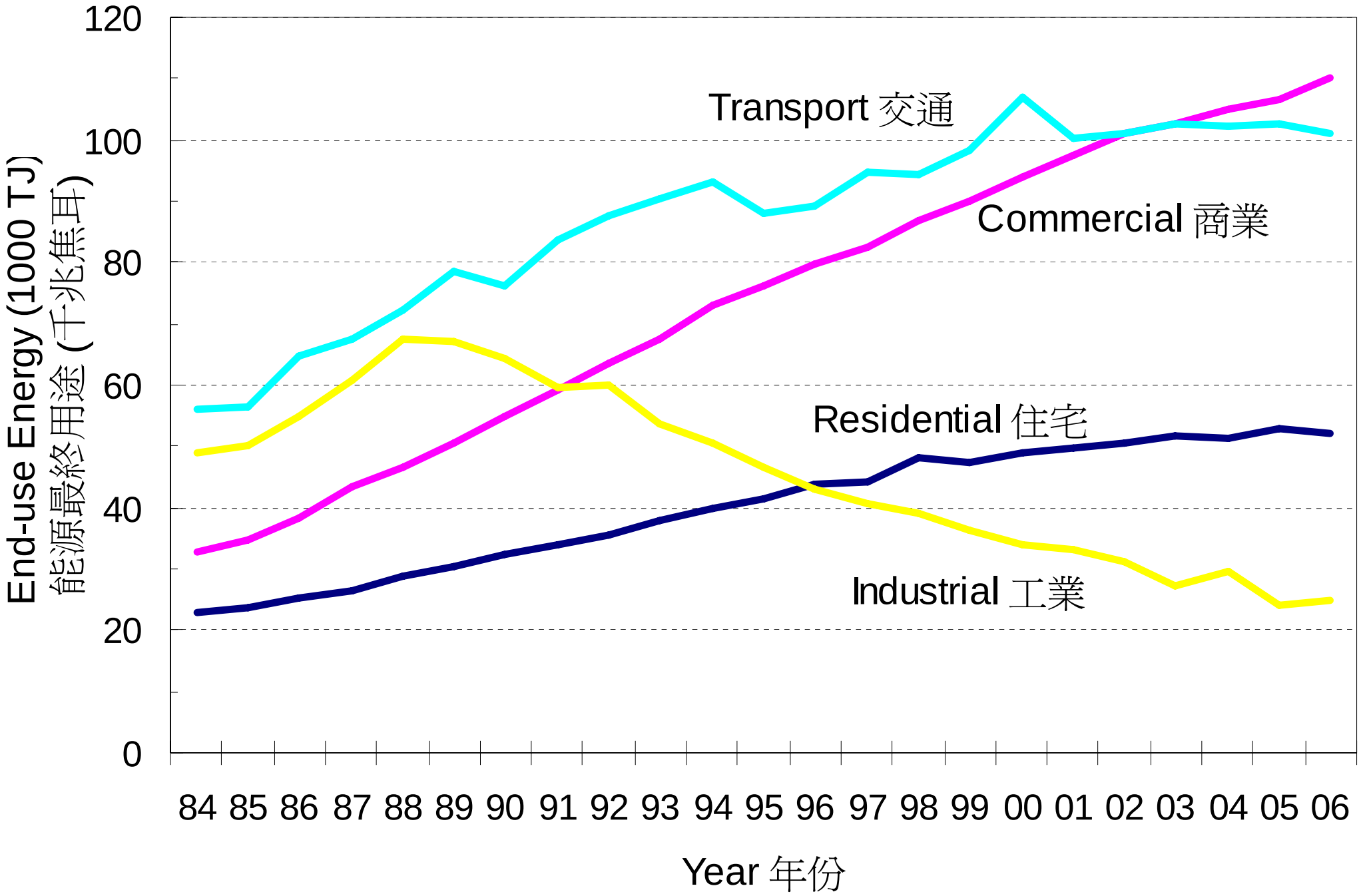


Energy Use in Buildings

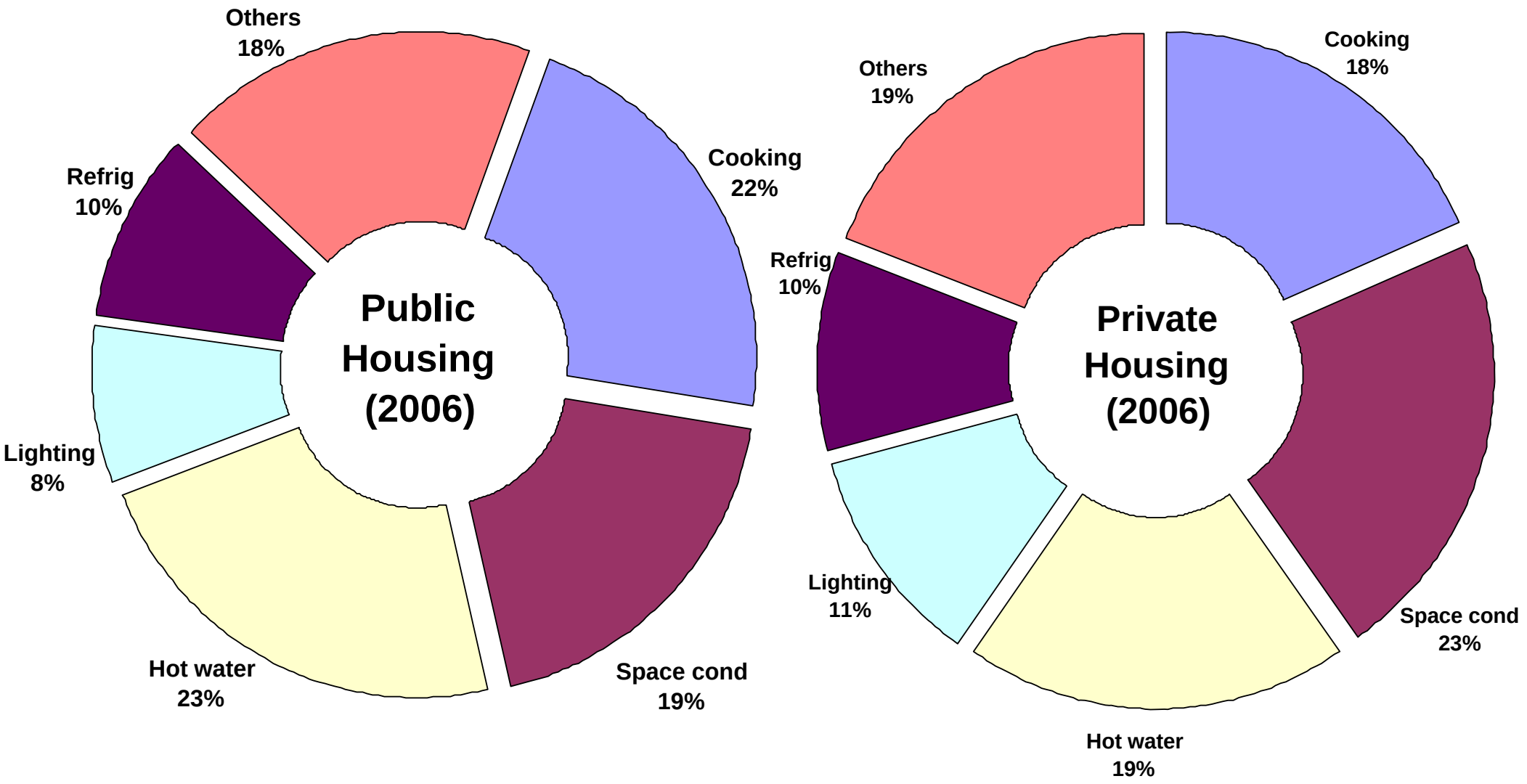
- Buildings constitute 30-50% of energy needs
  - Residential + commercial + industrial
  - The potential for energy saving is large
- The real cost of energy
  - Energy price
  - Environmental costs or externalities
    - e.g. $$ for pollution control & “repairing” of environmental damages
  - Need to internalise the externalities



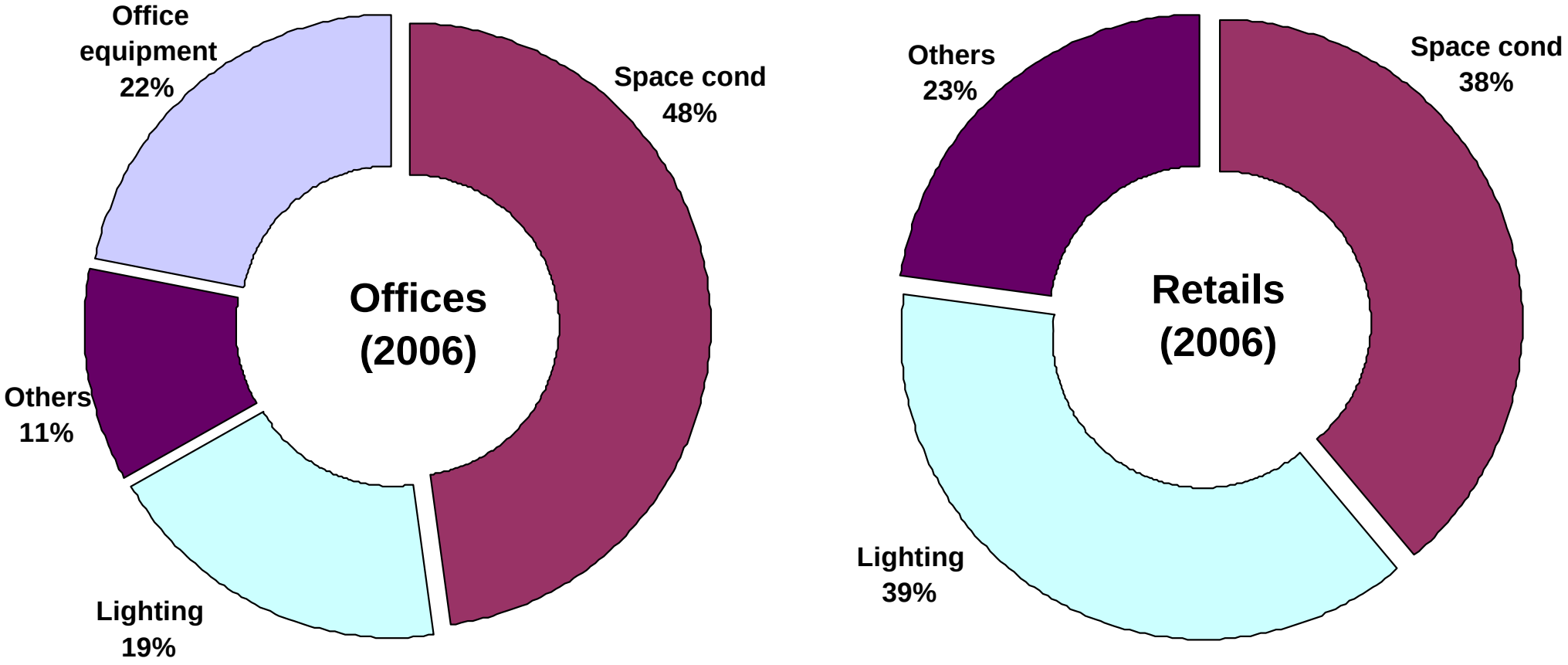
Energy end-use in Hong Kong 2005



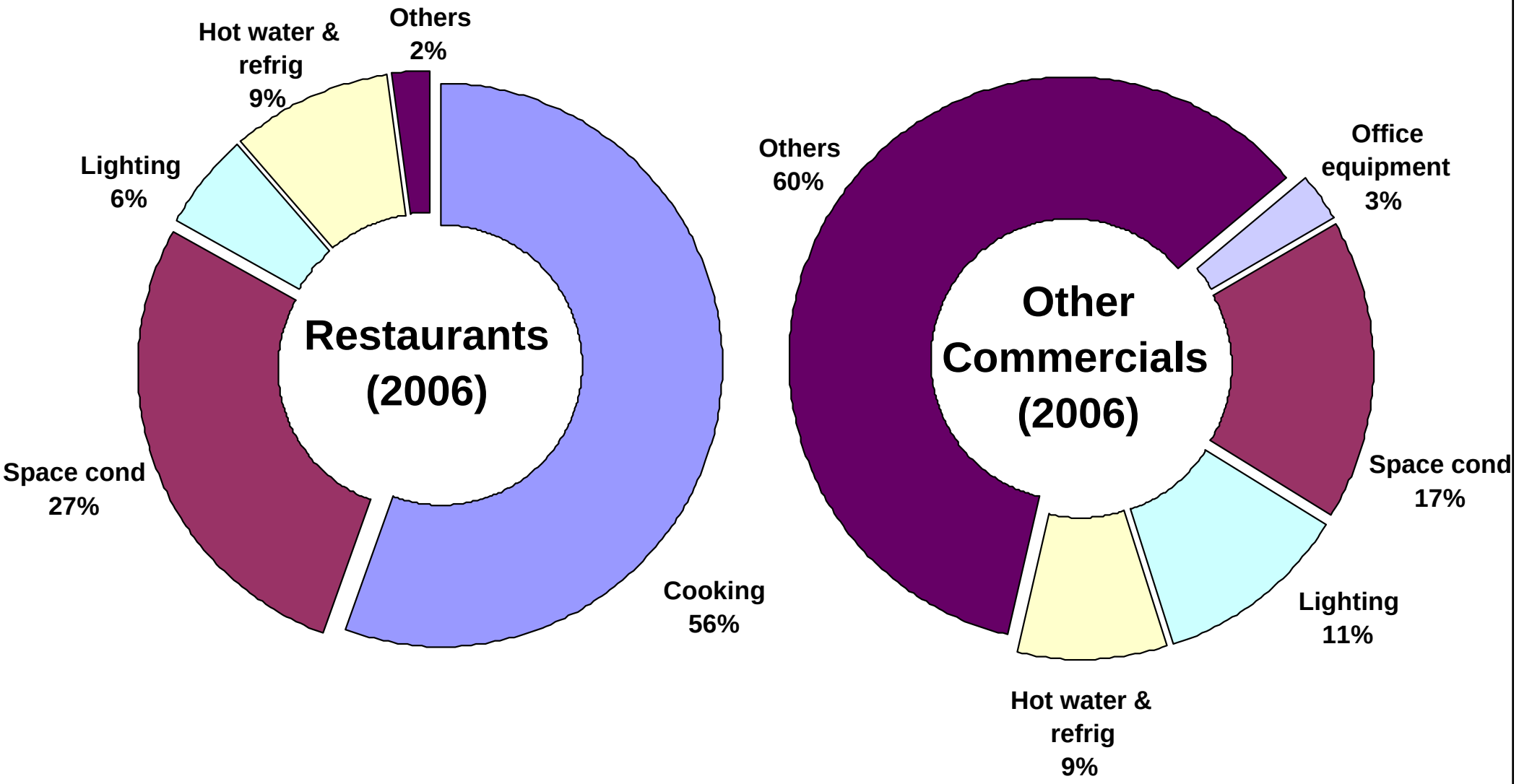
Energy end-use in Hong Kong by sectors, 1984-2006



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



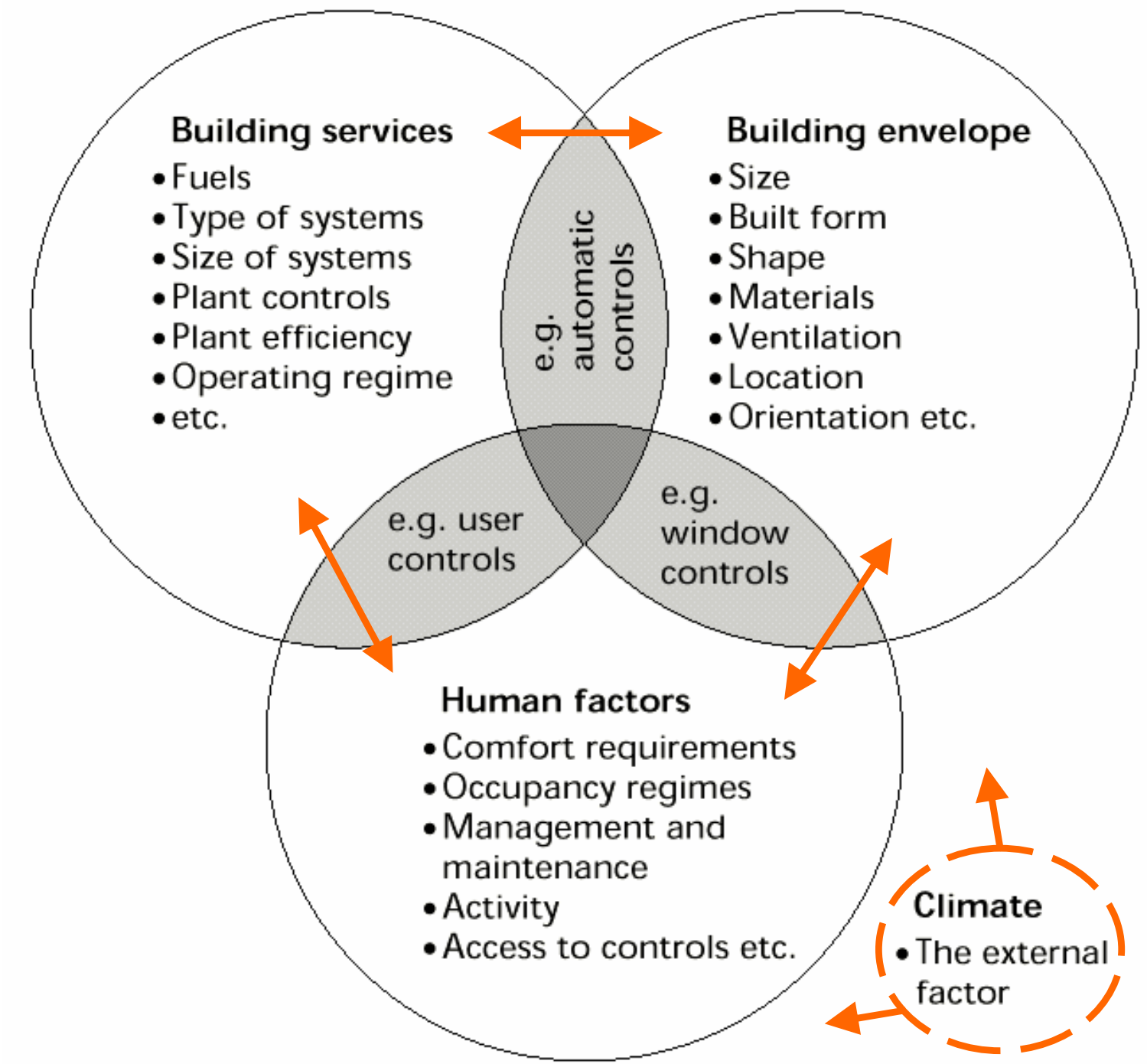
Energy consumption patterns in offices and retails
(Data source: Energy Efficiency Office, HK)



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

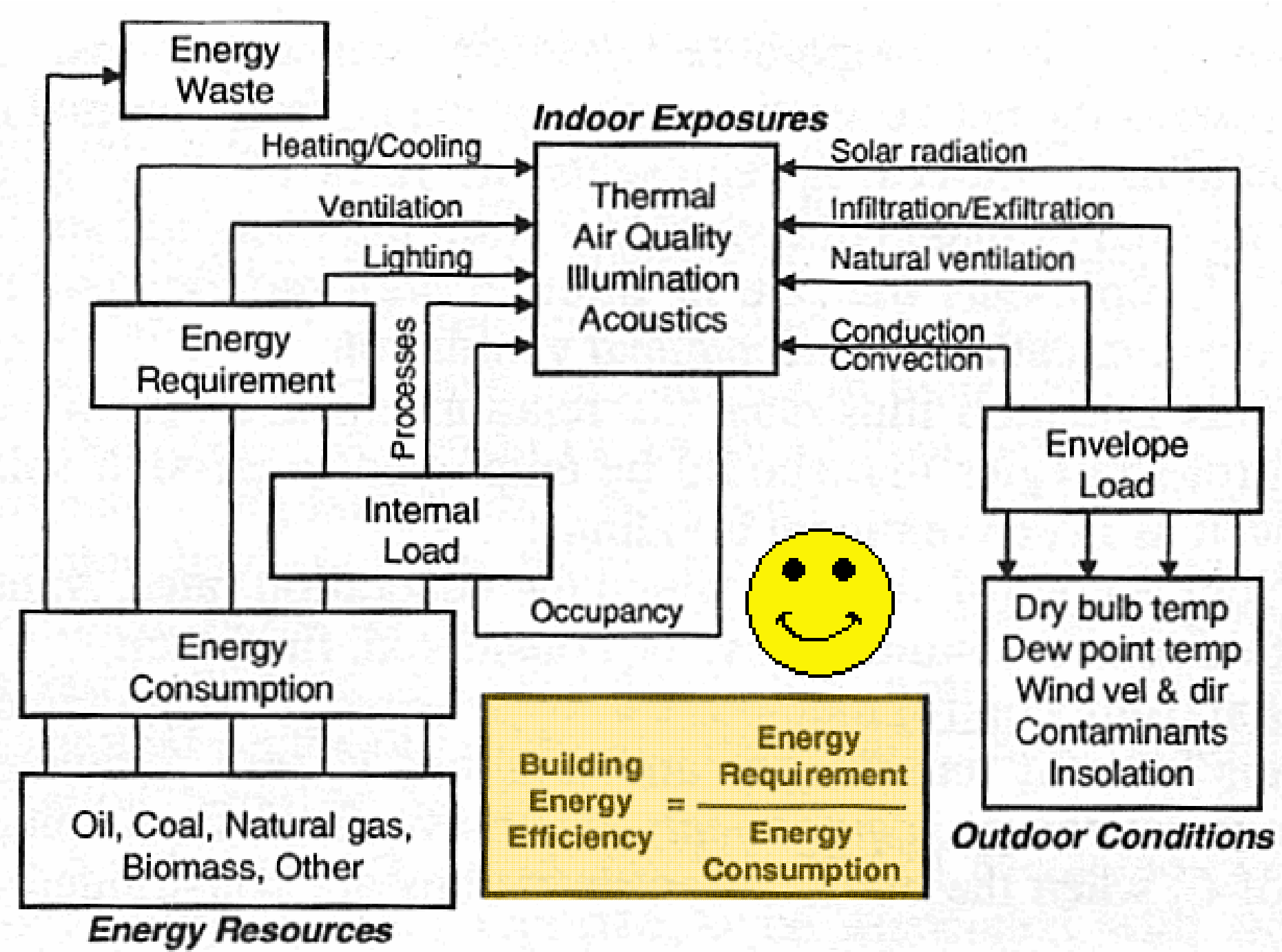
Energy Use in Buildings

- Possible benefits from energy efficiency:
  - Improved building design and operation
  - Better working environments
  - Life-cycle cost savings
  - Added market value of buildings
  - Reduced CO_2 emissions and consumption of finite fossil fuels
  - Reduced capital cost by better integration of building fabric and systems



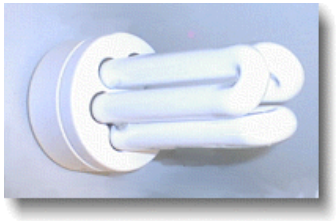
Key factors influencing energy consumption

(Source: Energy Efficiency in Buildings: CIBSE Guide F)



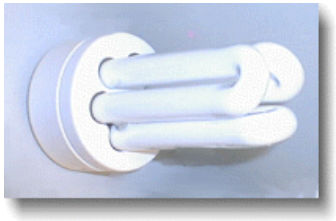
Energy flow and concept in buildings

Energy Efficiency

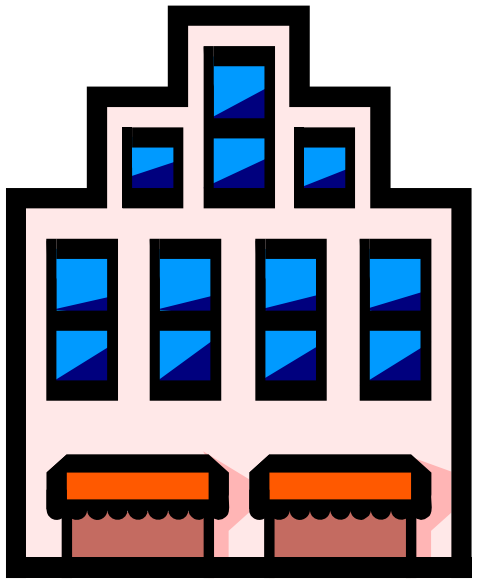


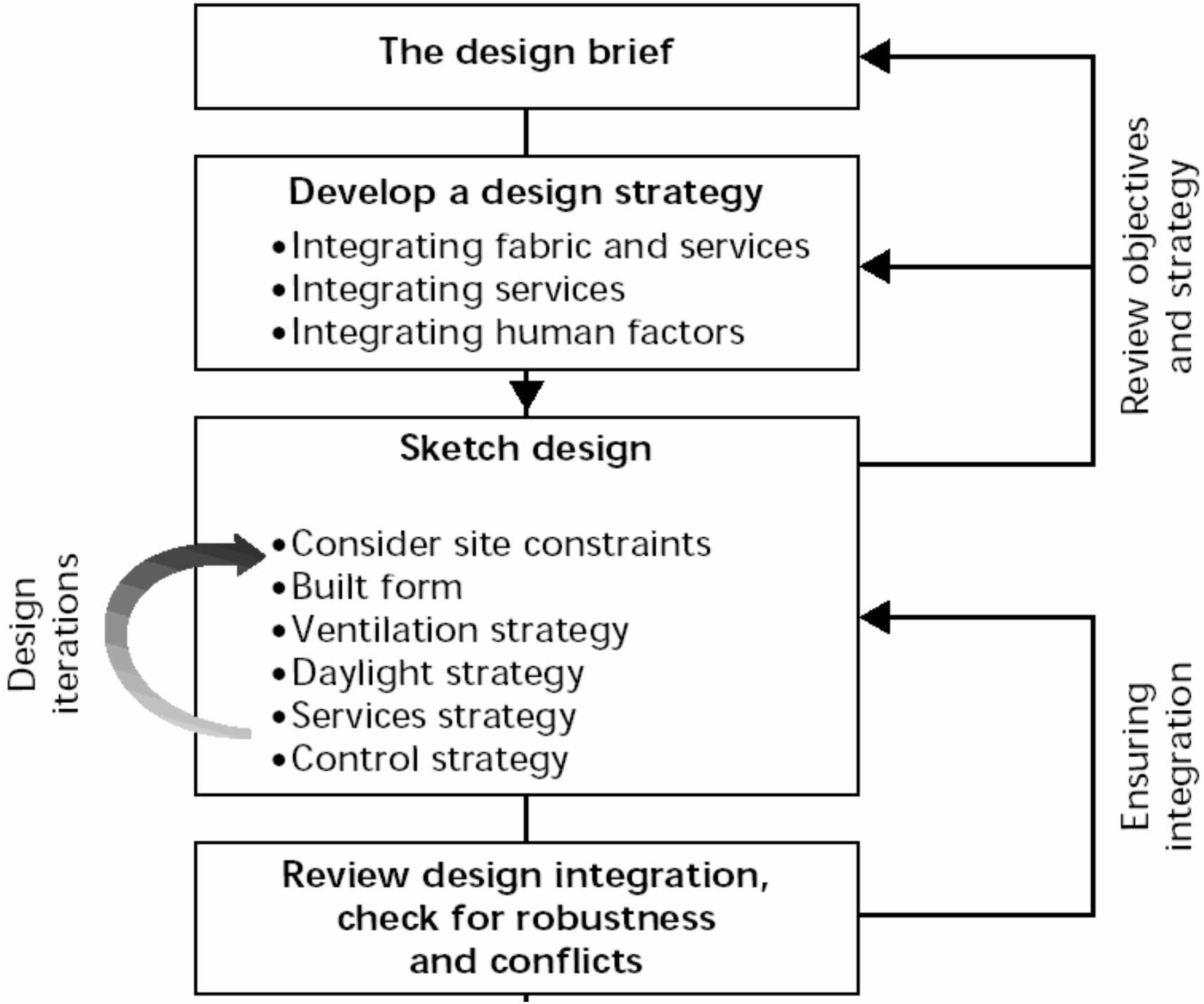
- "An energy efficient building provides the required internal environment and services with minimum energy use in a cost effective and environmentally sensitive manner." – *CIBSE Guide F: Energy Efficiency in Building*
  - Design energy efficient new buildings and refurbishment of existing buildings
  - Manage and operate buildings in an energy efficient way; Upgrade buildings to improve ongoing energy efficiency

Energy Efficiency

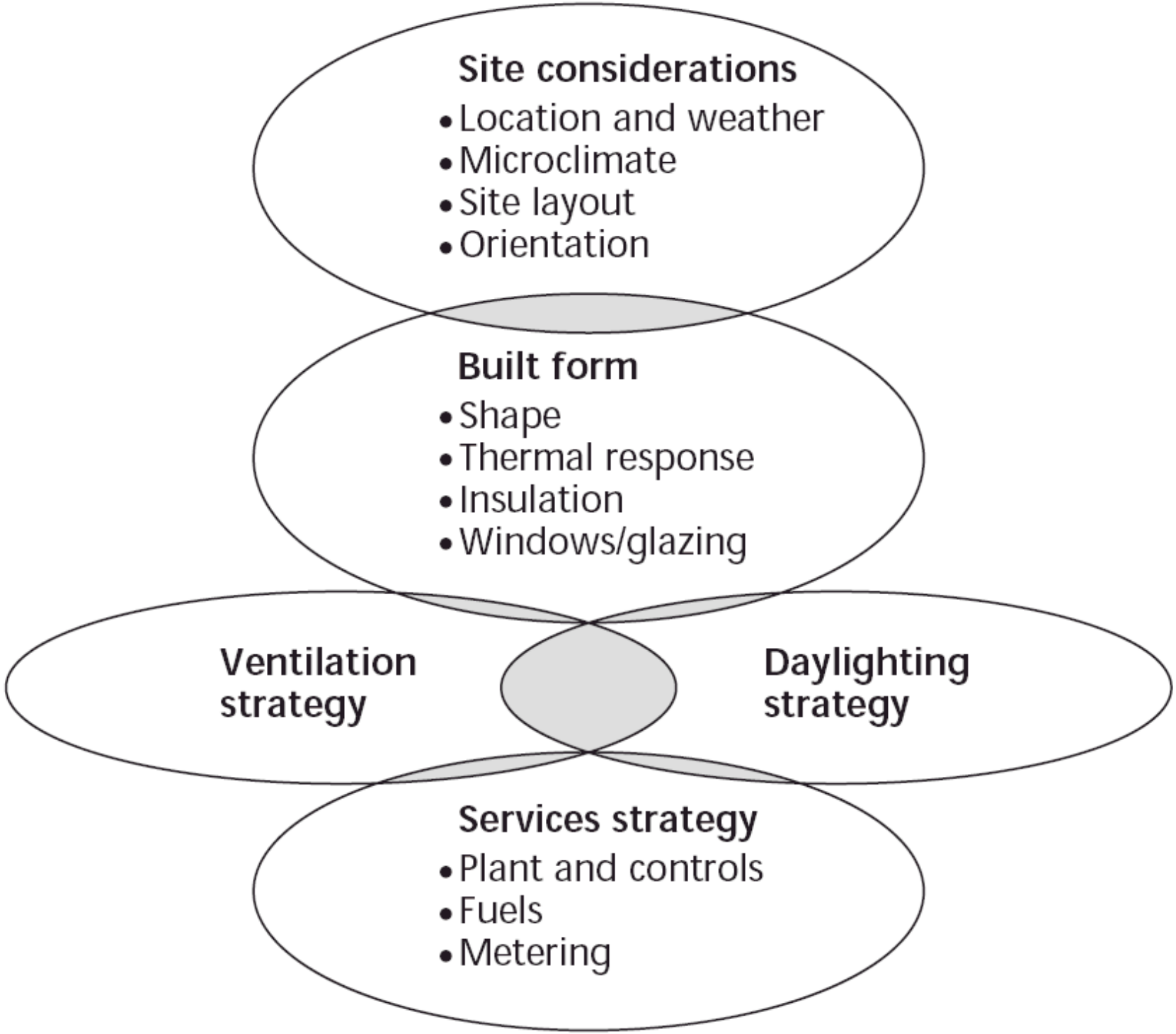


- For new buildings
  - Designing the building
    - Design strategy
    - Control strategies
    - Commissioning
- For existing buildings
  - Operating and upgrading the building
    - Building management
    - Refurbishment/renovation/retrofitting
    - Maintenance and monitoring



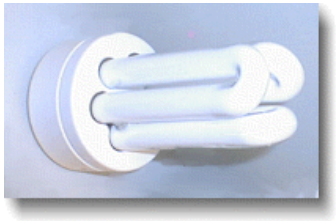


(Source: Energy Efficiency in Buildings: CIBSE Guide F)

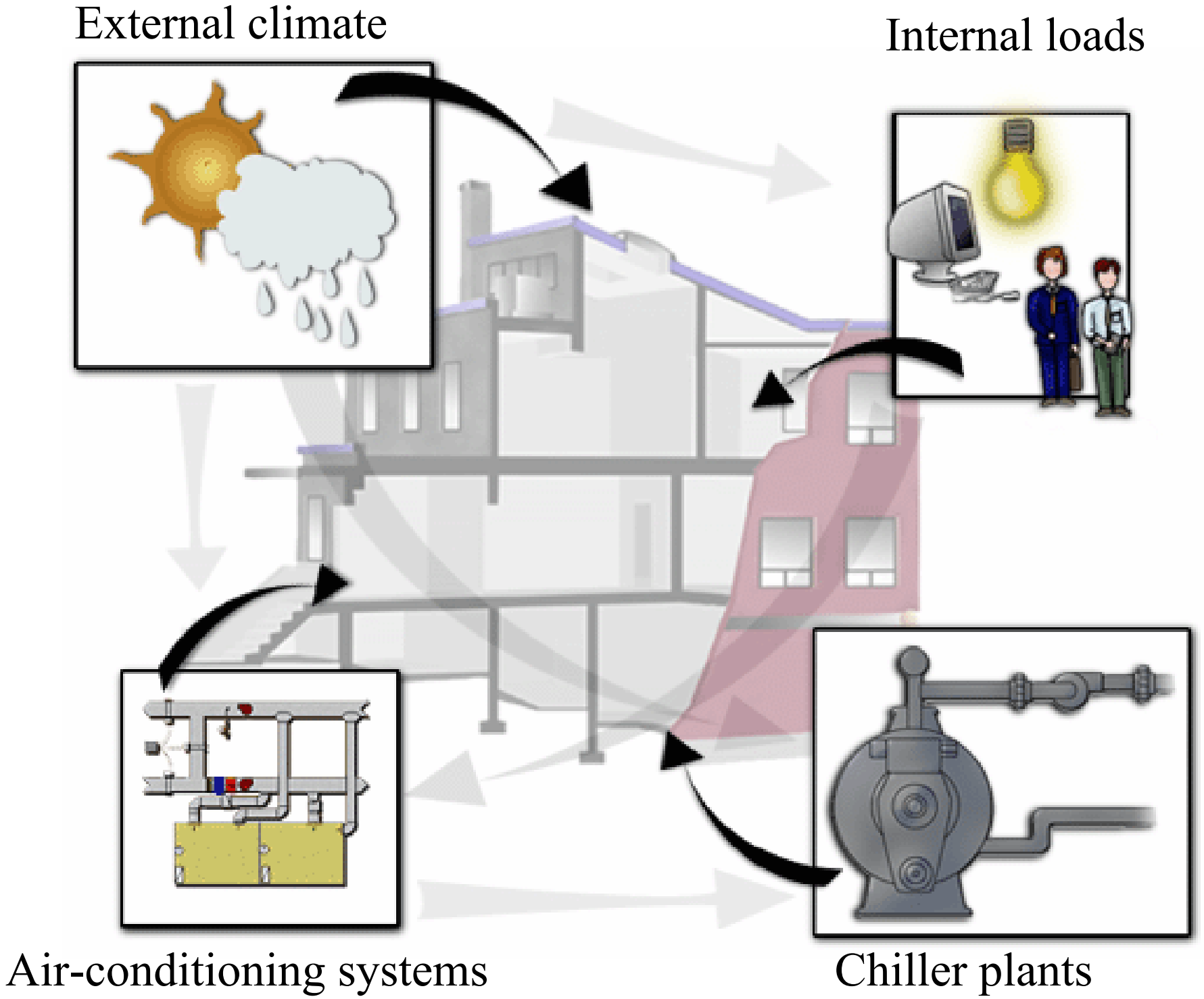


(Source: Energy Efficiency in Buildings: CIBSE Guide F)

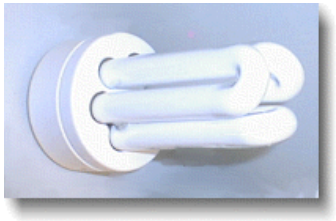
Energy Efficiency



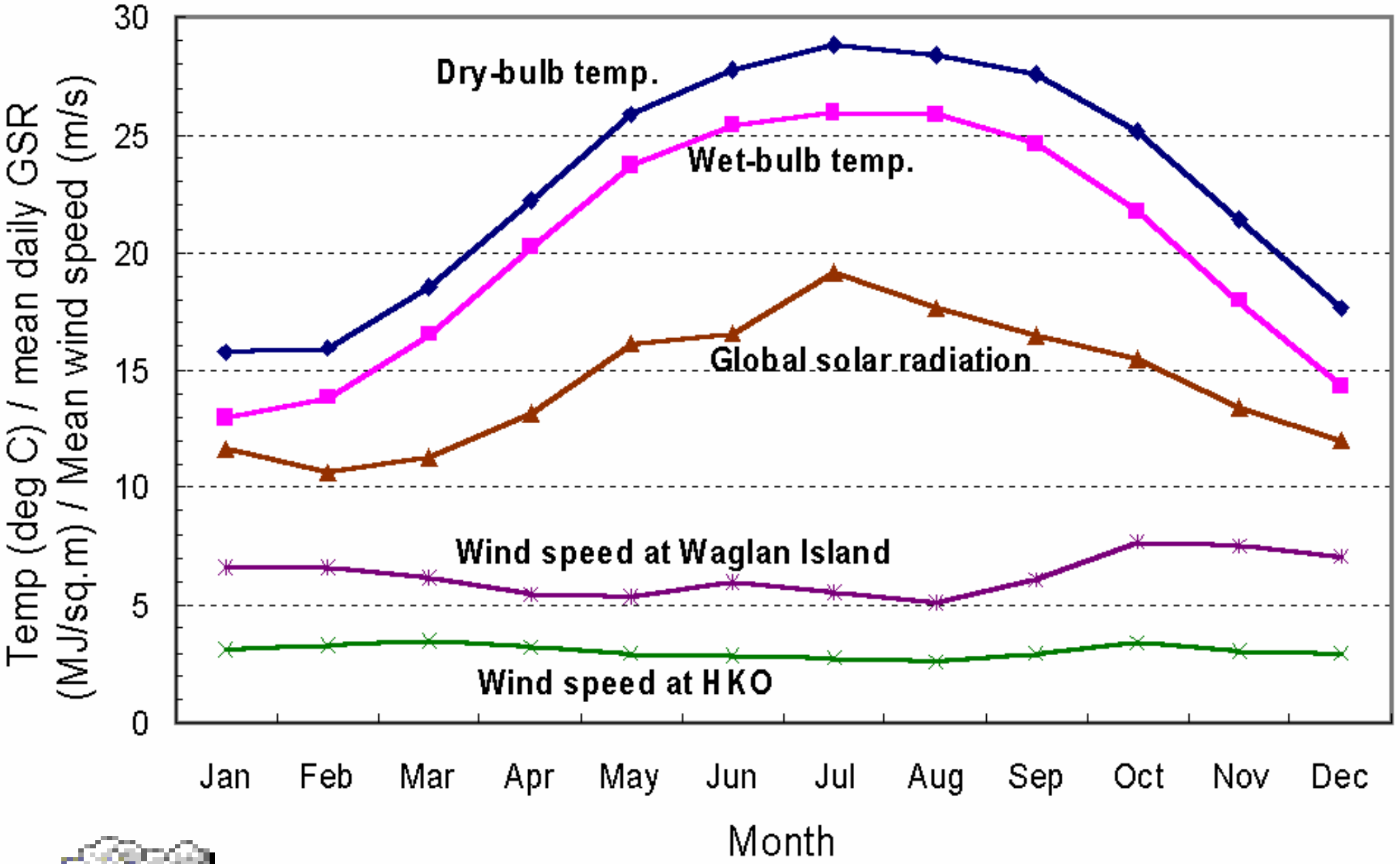
- Efficient use of energy
  - Reduce energy consumption
  - Optimise building's performance
- Major factors
  - Response to local climate (temp., humidity, solar)
  - Building envelope (skin) design
  - Building services systems
  - Human factors & building operation


External climate
Internal loads
Air-conditioning systems
Chiller plants

Energy Efficiency



- Climate
  - It has a major effect on building thermal and energy performance
- Response of a building to climate:
  - Thermal response of building structure
  - Response of HVAC and lighting systems
- Building design must “fit” its climate
  - Human comfort and bioclimatic design

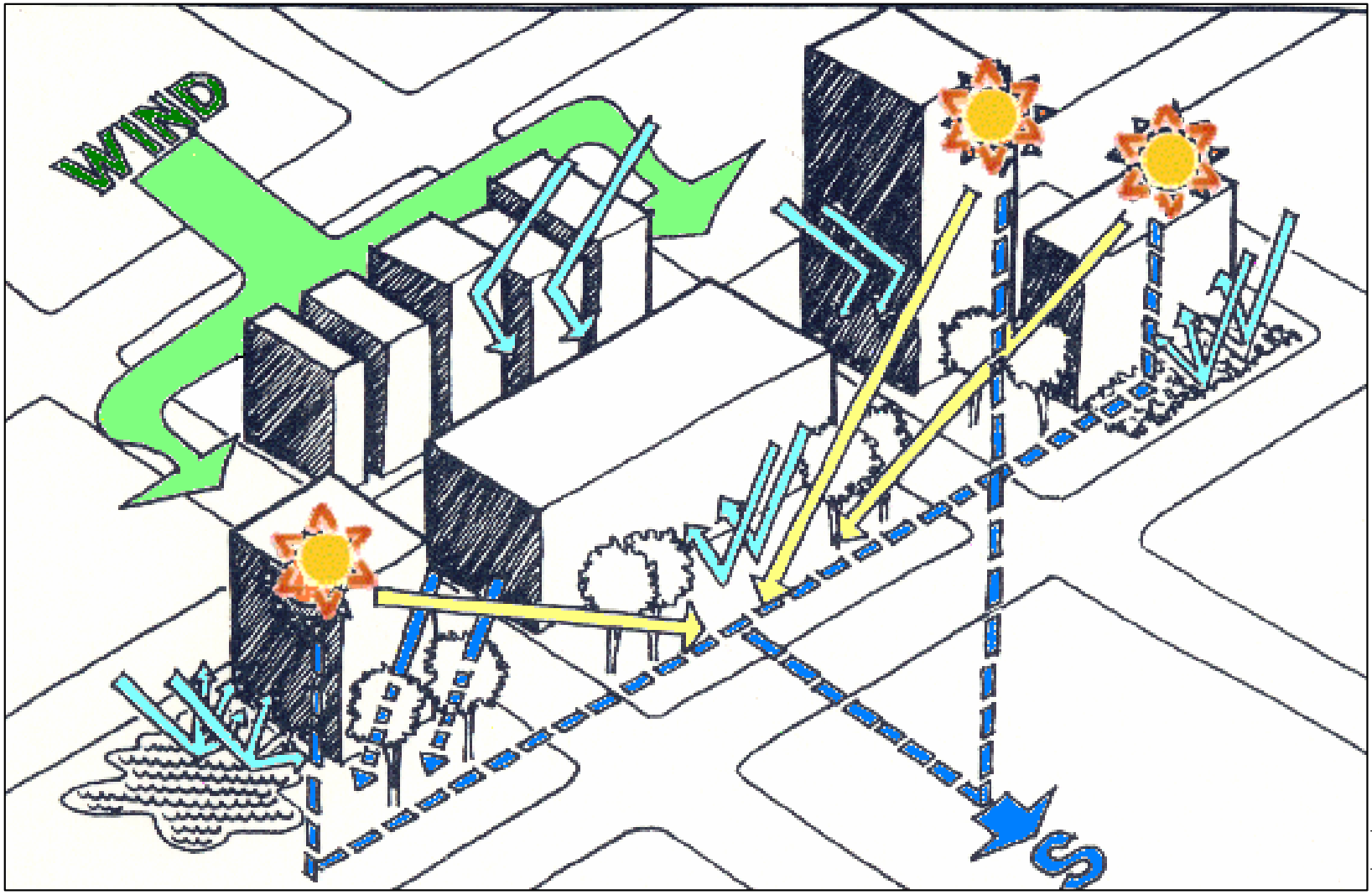


Major climatic elements of Hong Kong

Building designer is like a “Feng Shui” master.

風
Wind

光
Light

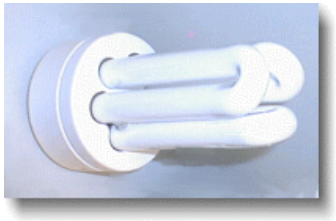


水
Water

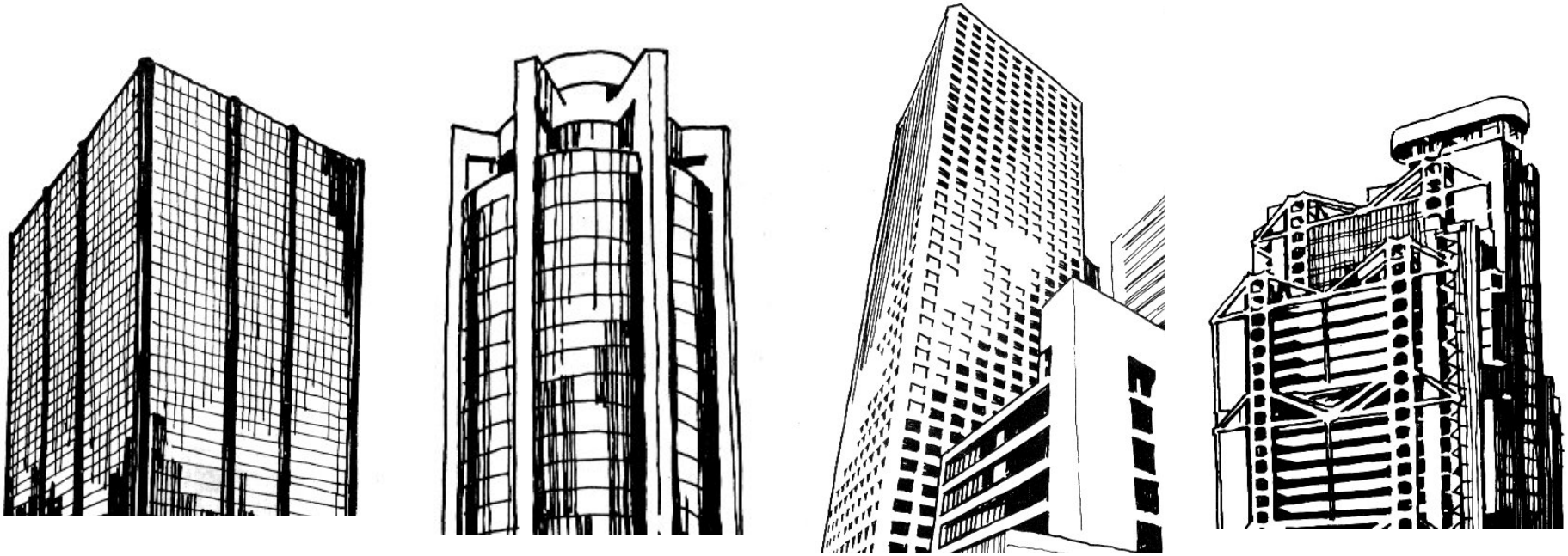
物
Matter

Major site factors

Energy Efficiency



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



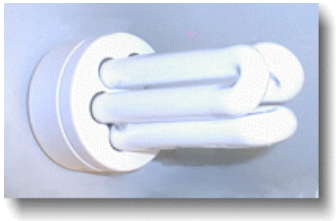
Building envelope designs of commercial buildings
in Hong Kong
(Which one is more energy efficient?)

Look at me.
Is my face (building envelope) energy efficient?

Main criteria:
- wall area
- window area
- thermal properties
- orientations
- thermal mass
- shading device

* Face House, Kyoto, Japan

Energy Efficiency

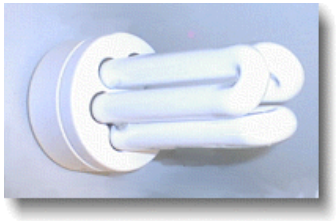


- Major factors determining envelope heat flow:
  - Temperature differential, ΔT
  - Area of exposed building surfaces, A
  - Heat transmission properties, like U-value
  - Thermal storage capacity

$$Q = U A \Delta T$$

- Effect of thermal mass
  - Delay heat transfer or act as a cooling source
  - Important for intermittently cooled spaces

Energy Efficiency



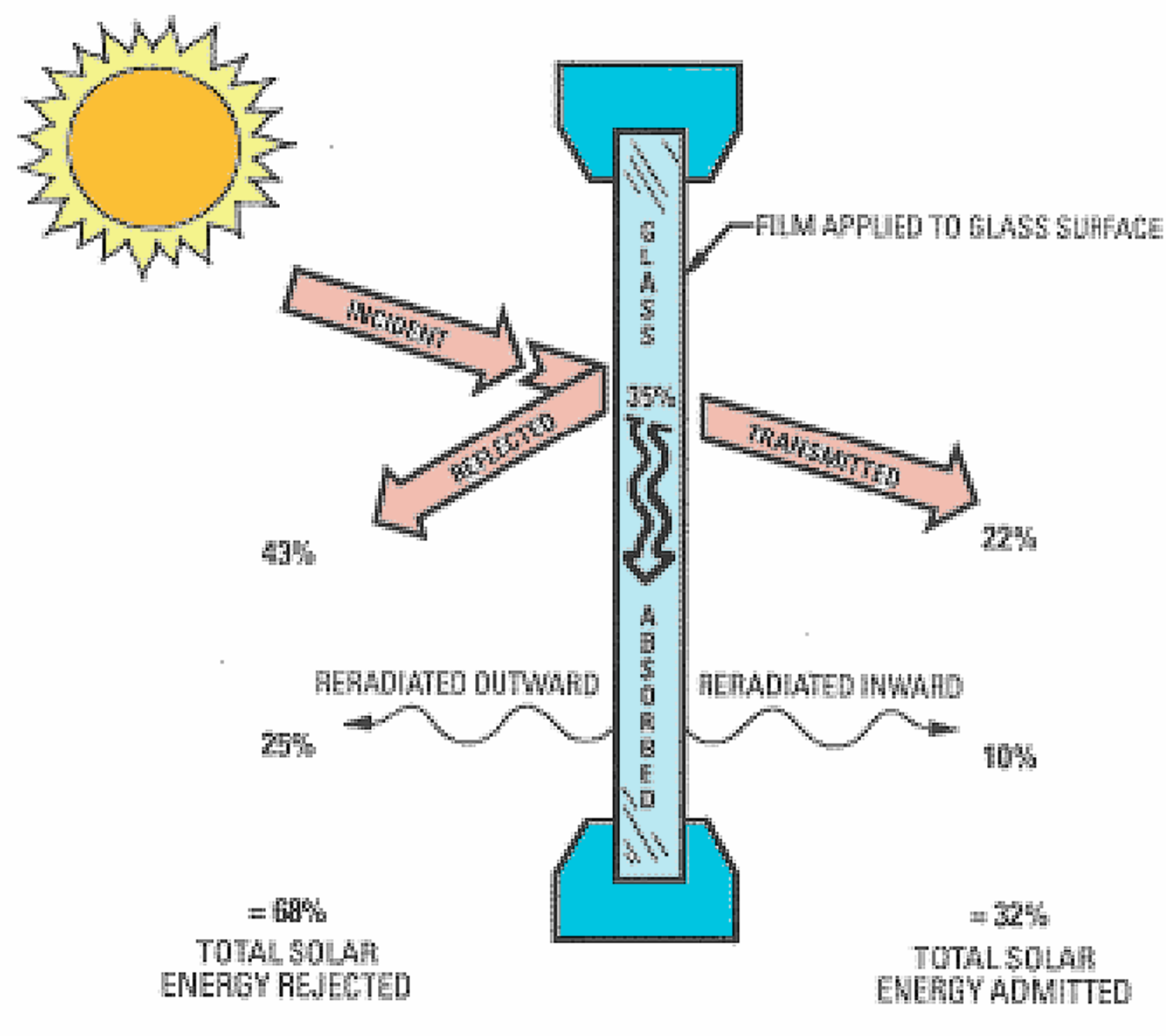
- Complicated issues with building envelope:
  - Dynamic behaviour of climate and building
  - Interaction of light and heat
  - Use of daylighting and solar energy systems
- Possible energy saving options for envelope:
  - Select appropriate window design and materials
  - Design thermal insulation and building fabric
  - Apply sun control window films

Single Glazed, Clear

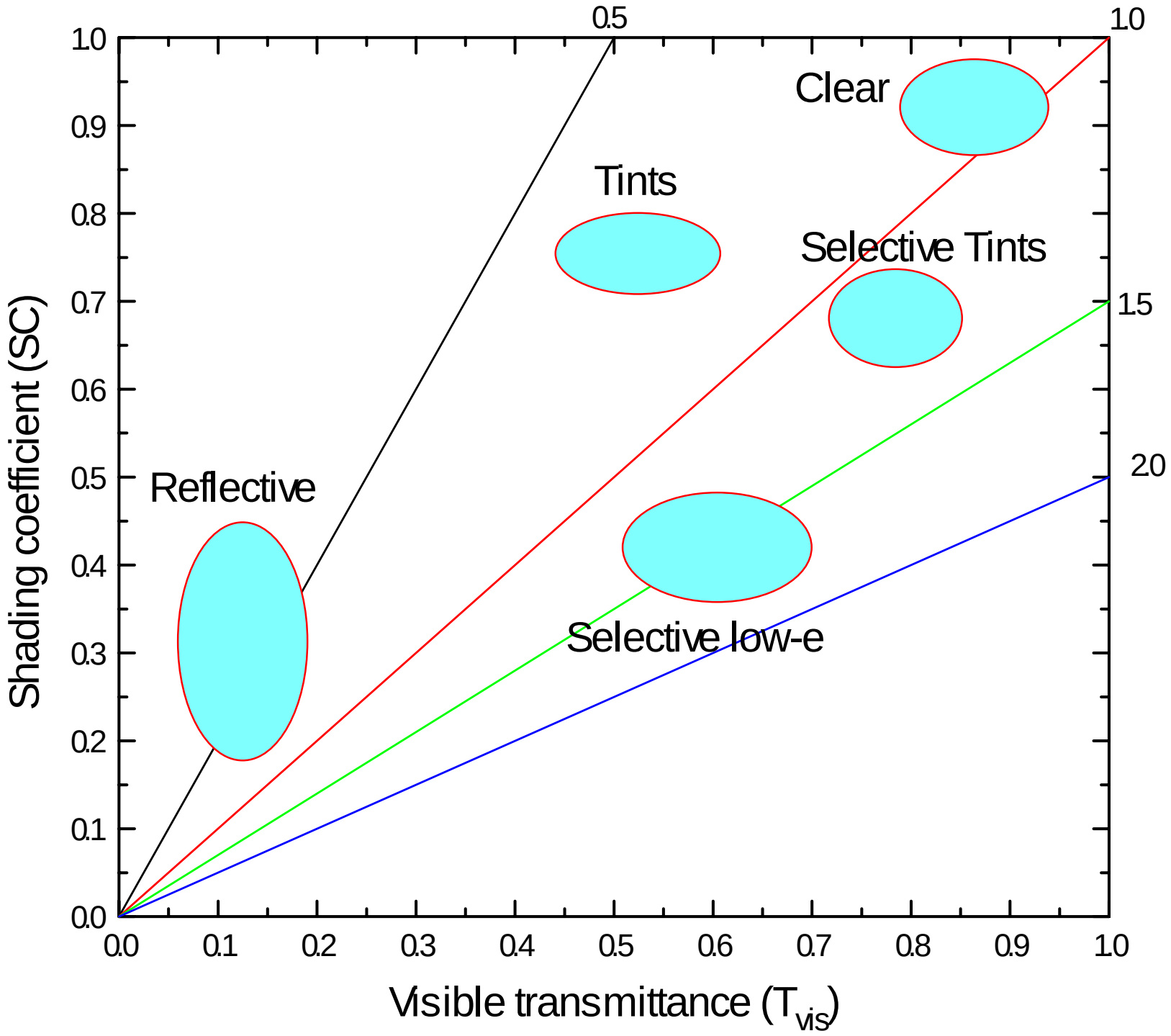
Double Glazed, Clear

Double Glazed, low-e

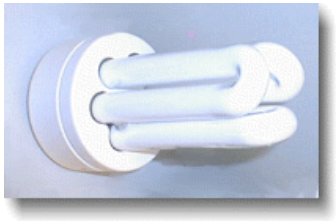
Triple Glazed, low-e



Solar heat gain through window glass

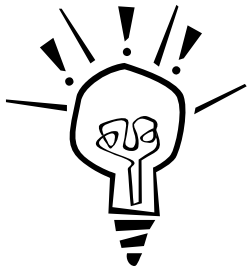
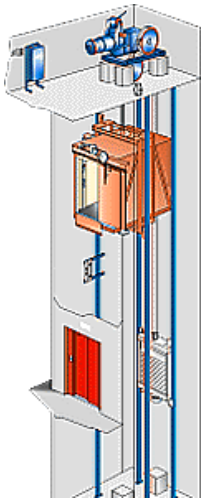
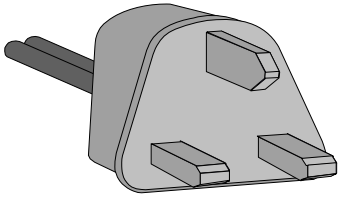


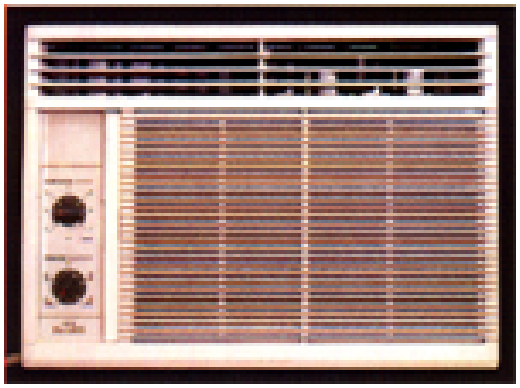
Properties of window glasses

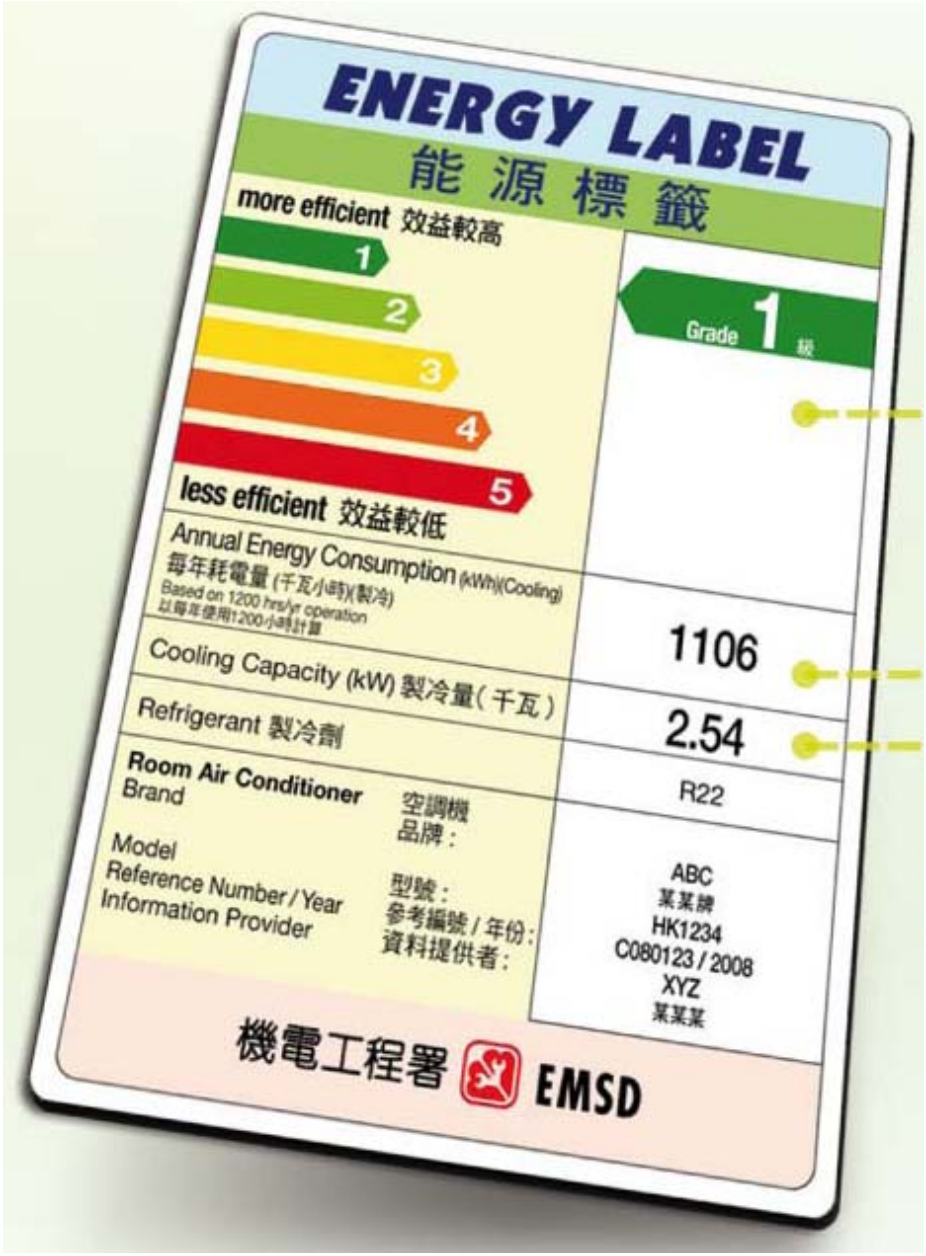


Energy Efficiency

- Building services systems
  - Air-conditioning
  - Lighting
  - Electrical services
  - Lifts & escalators
  - Plumbing & drainage
  - Town gas supply
  - Building management

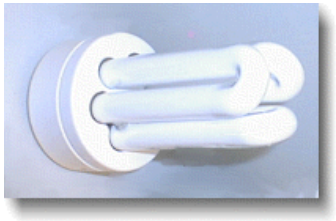





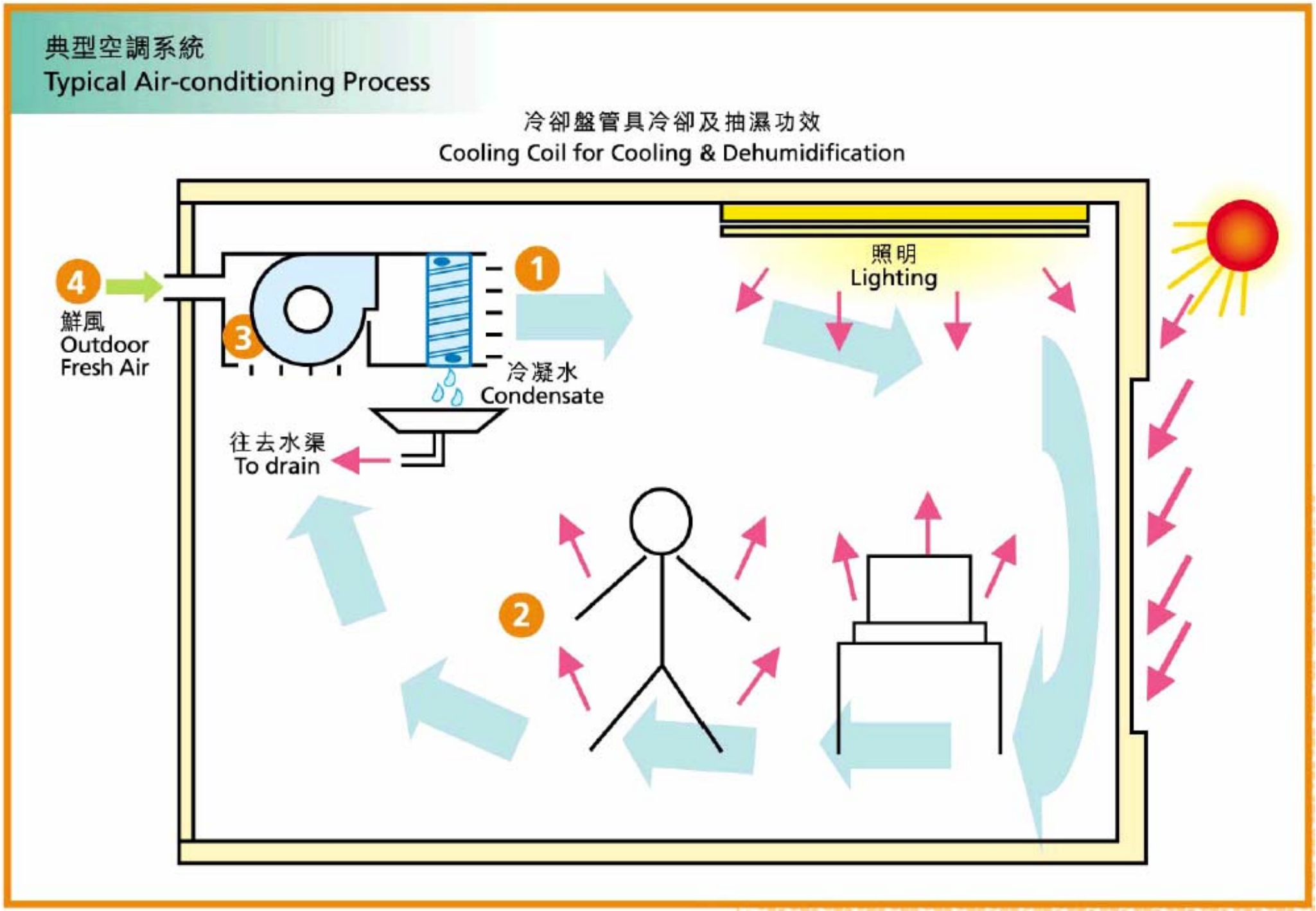


Energy label for appliances and equipment

Energy Efficiency

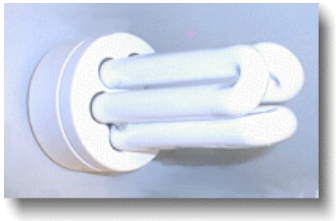


- Heating, ventilating & air-conditioning (HVAC) systems
  - Usually the most important energy users
  - Provide for occupant comfort, health and safety
  - HVAC design is affected by architectural features and occupant needs
- In Hong Kong, heating load is small and main focus is on air-conditioning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

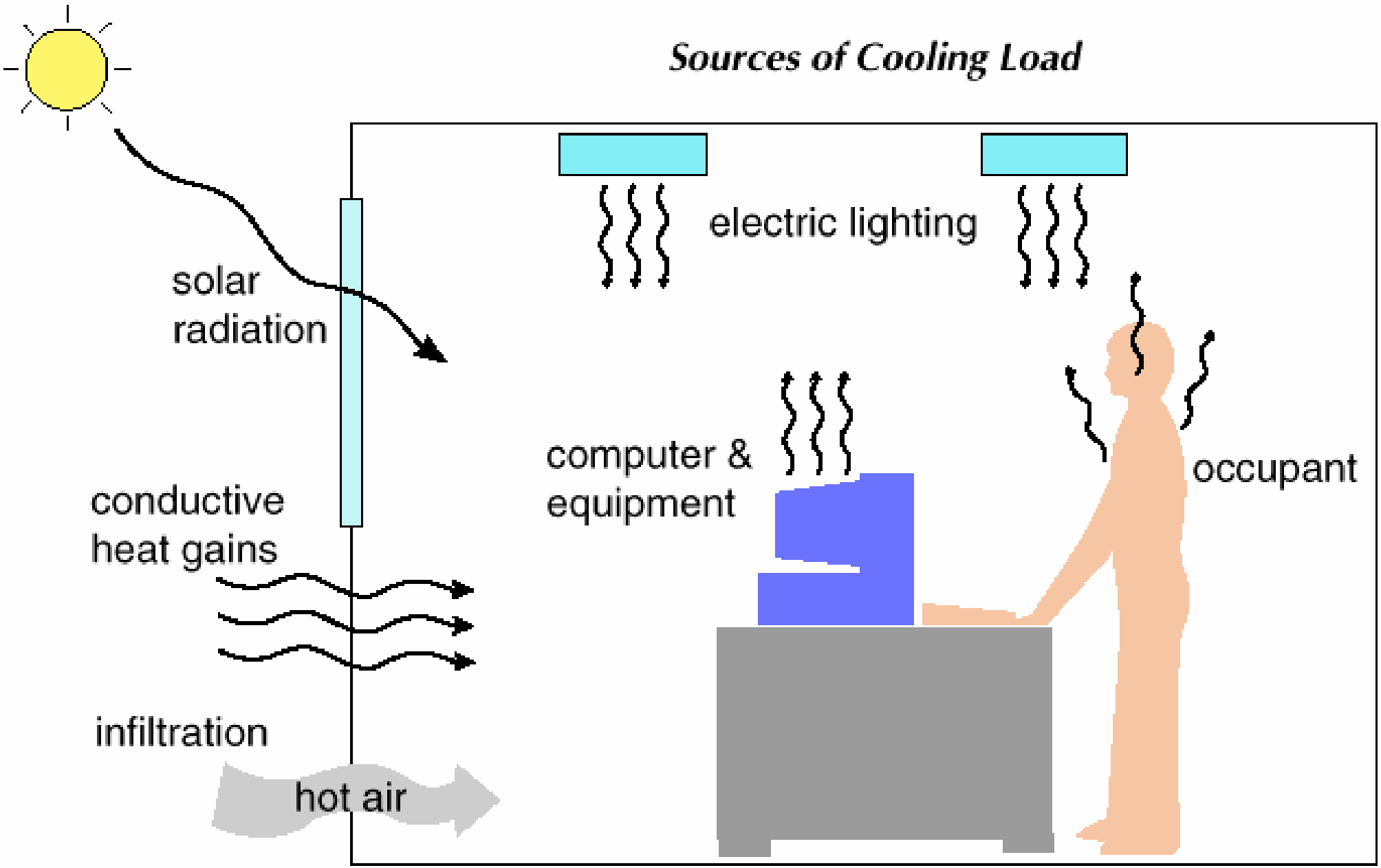


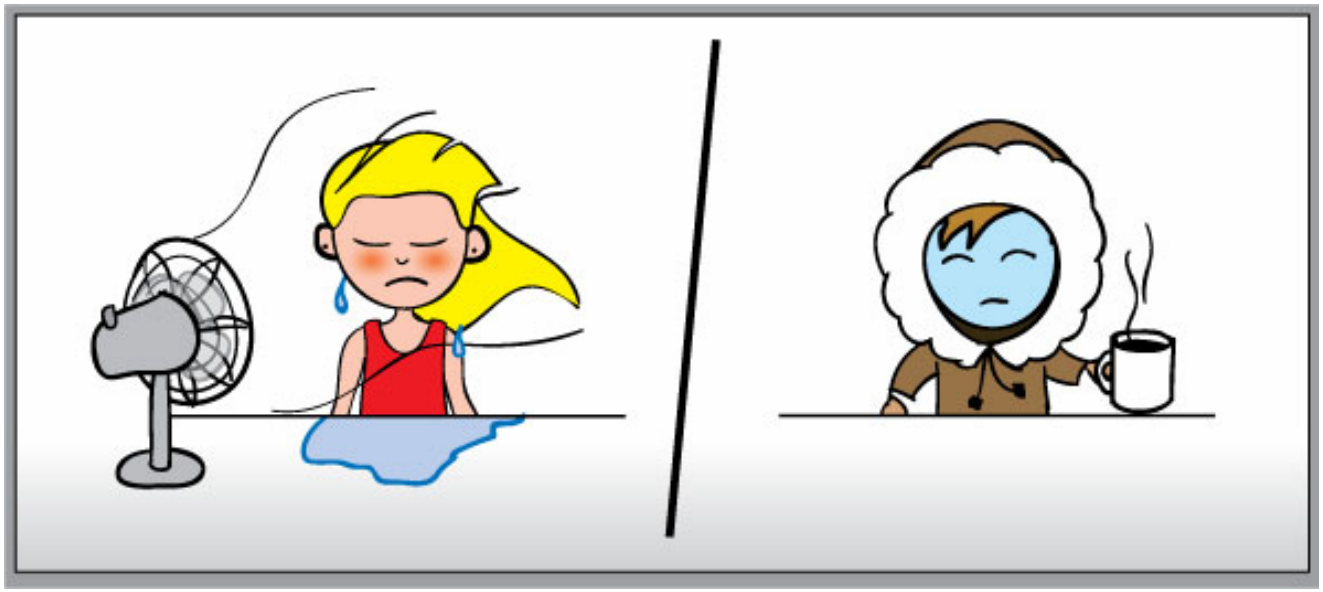
(Source: EnergyWitts newsletter, EMSD)

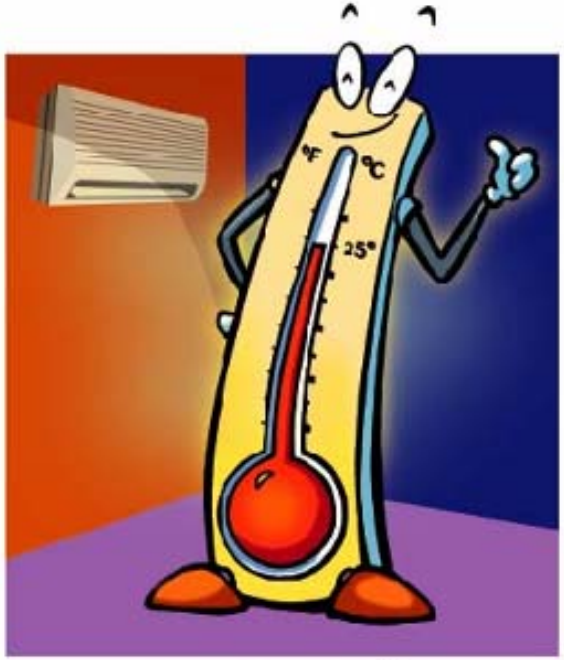
Energy Efficiency



- Strategies for energy efficiency of HVAC
  - 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


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



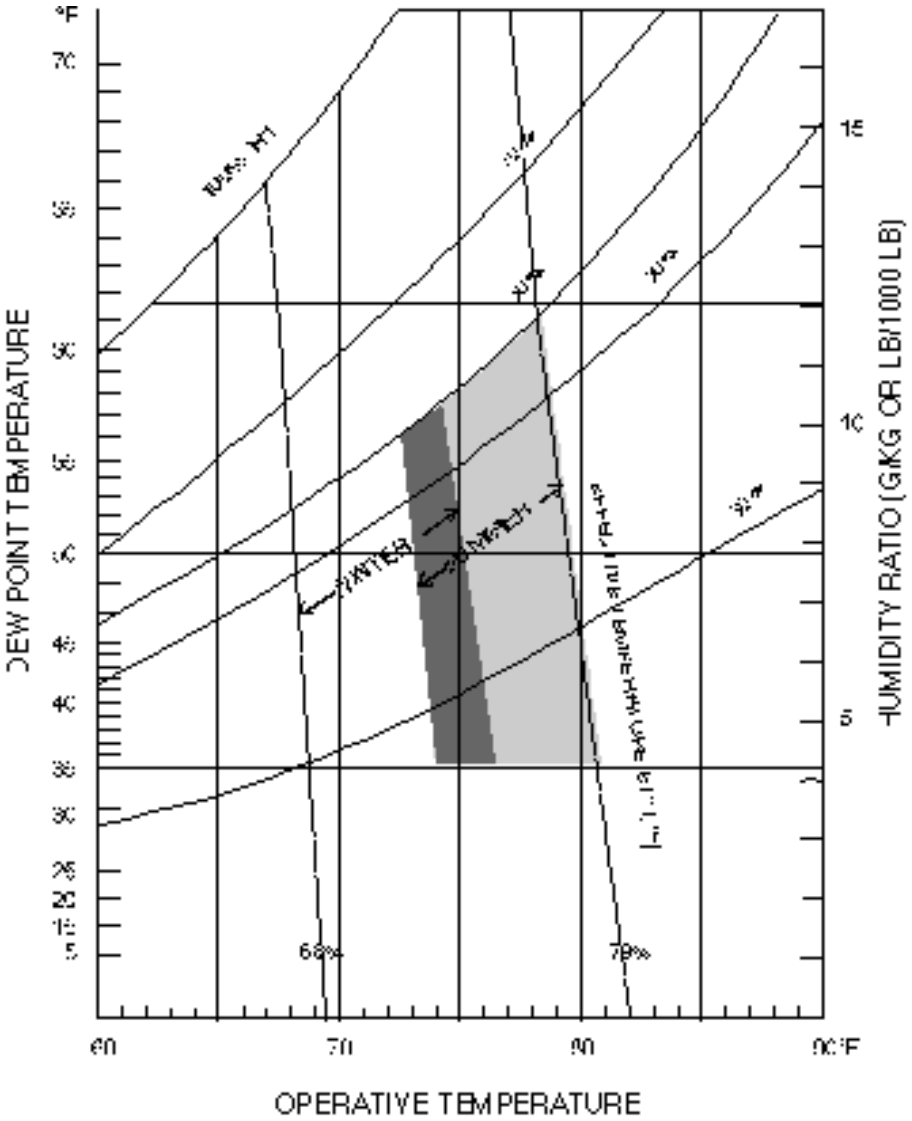


Just nice at 25°C

Electricity Efficiency Centre

Cleaner filter filters better.

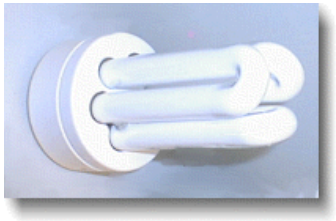
Electricity Efficiency Centre



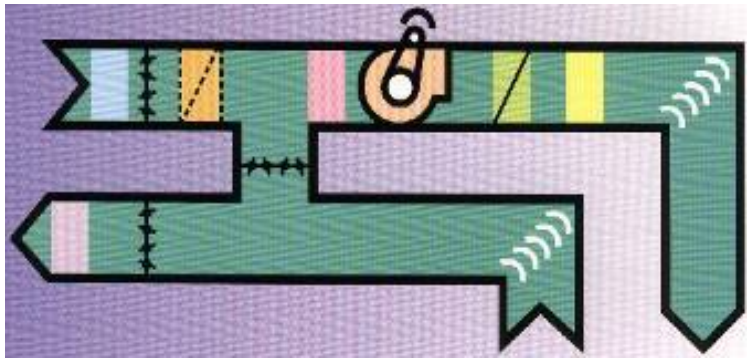
ASHRAE comfort envelope

Thermal comfort & design conditions

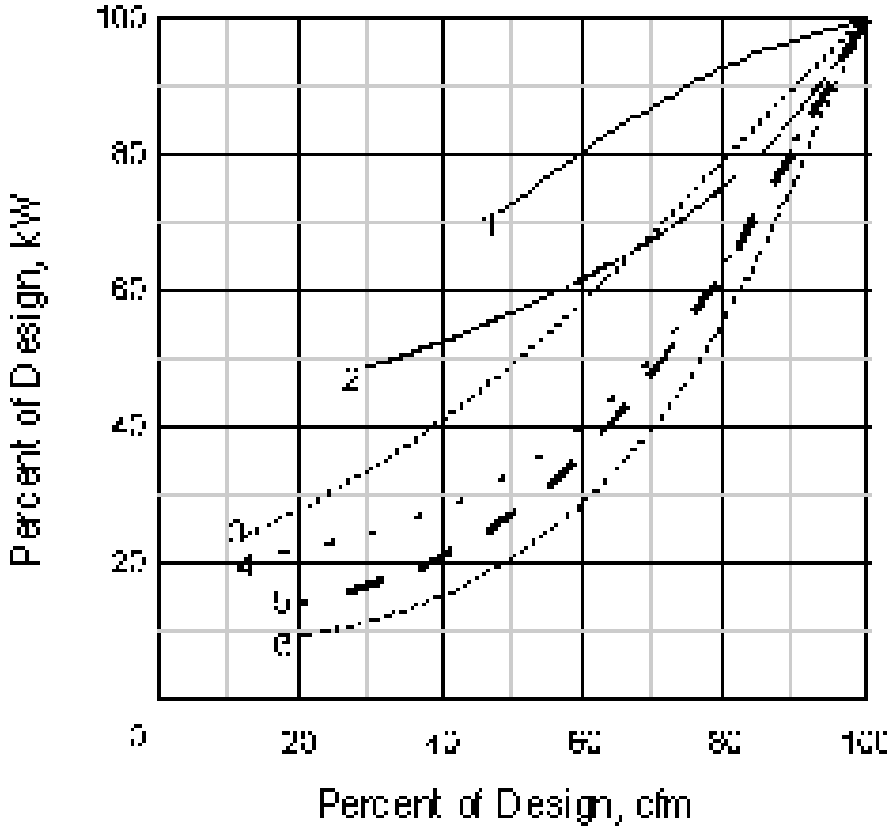
Energy Efficiency



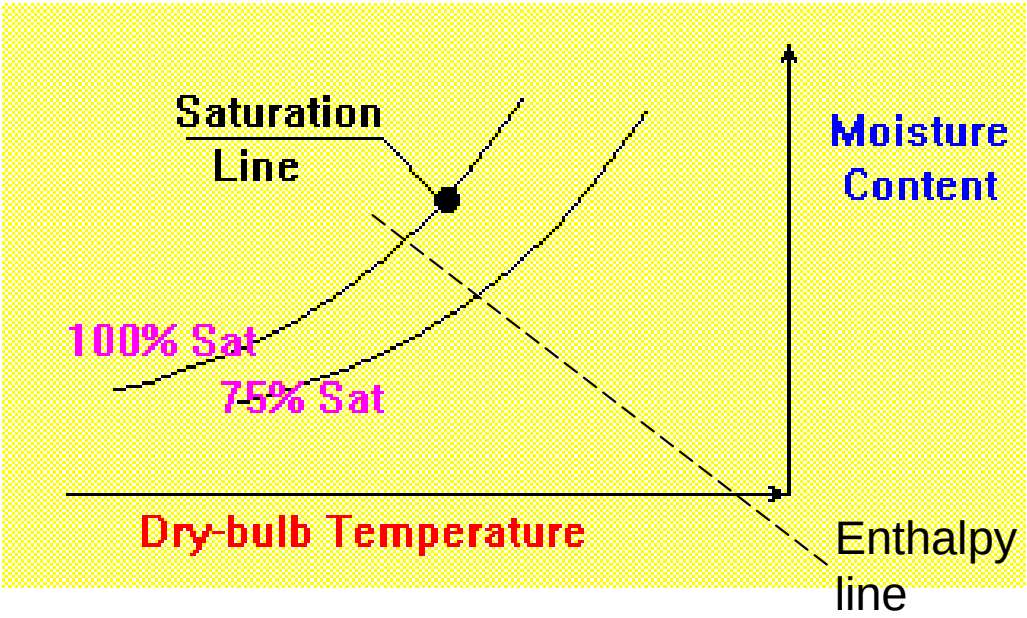
- HVAC system design and operation
  - System characteristics
    - Type of systems
    - Energy efficiency ratios
    - Coefficient of performance
    - System operation & control
  - Equipment and plant operation
    - Especially during partload conditions
    - Opportunity for heat recovery
    -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

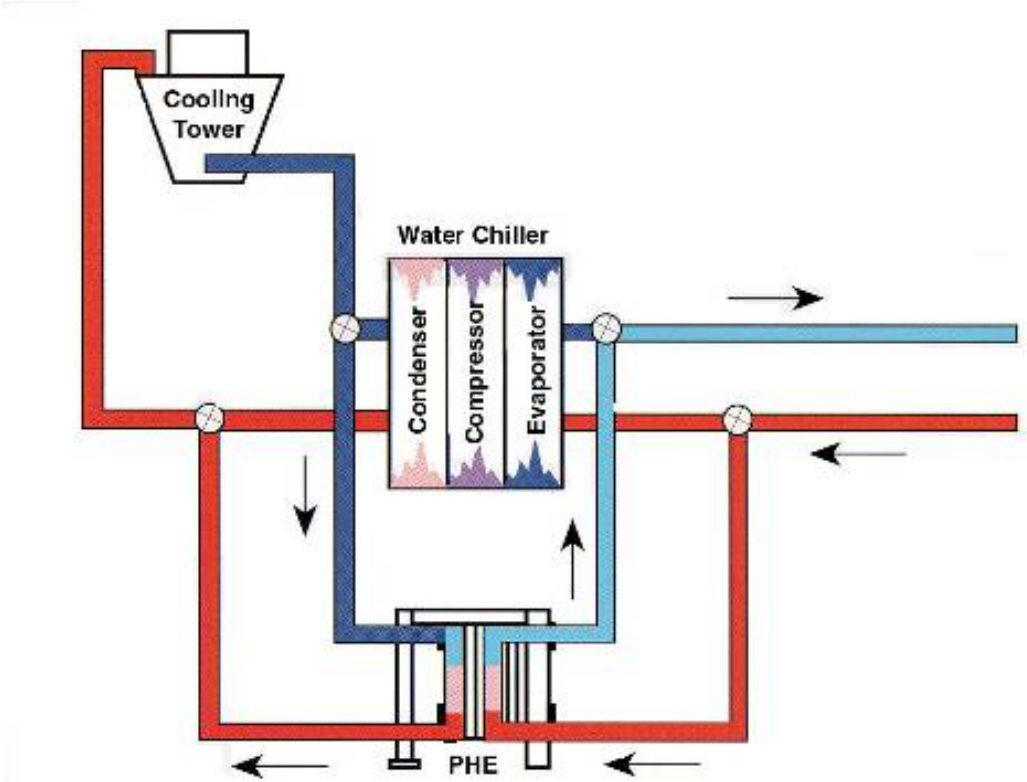


HVAC system and plant



Partload curves for fans

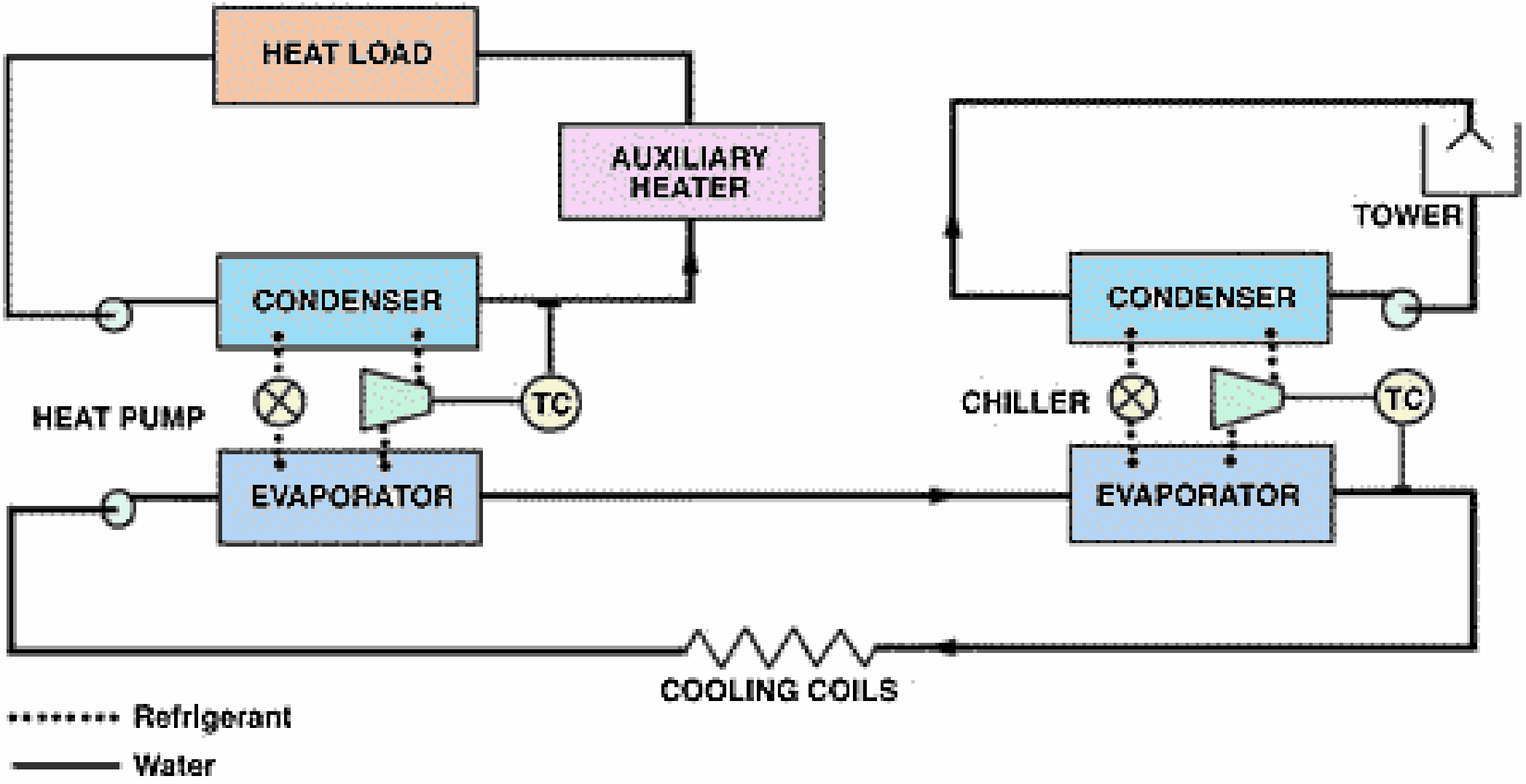




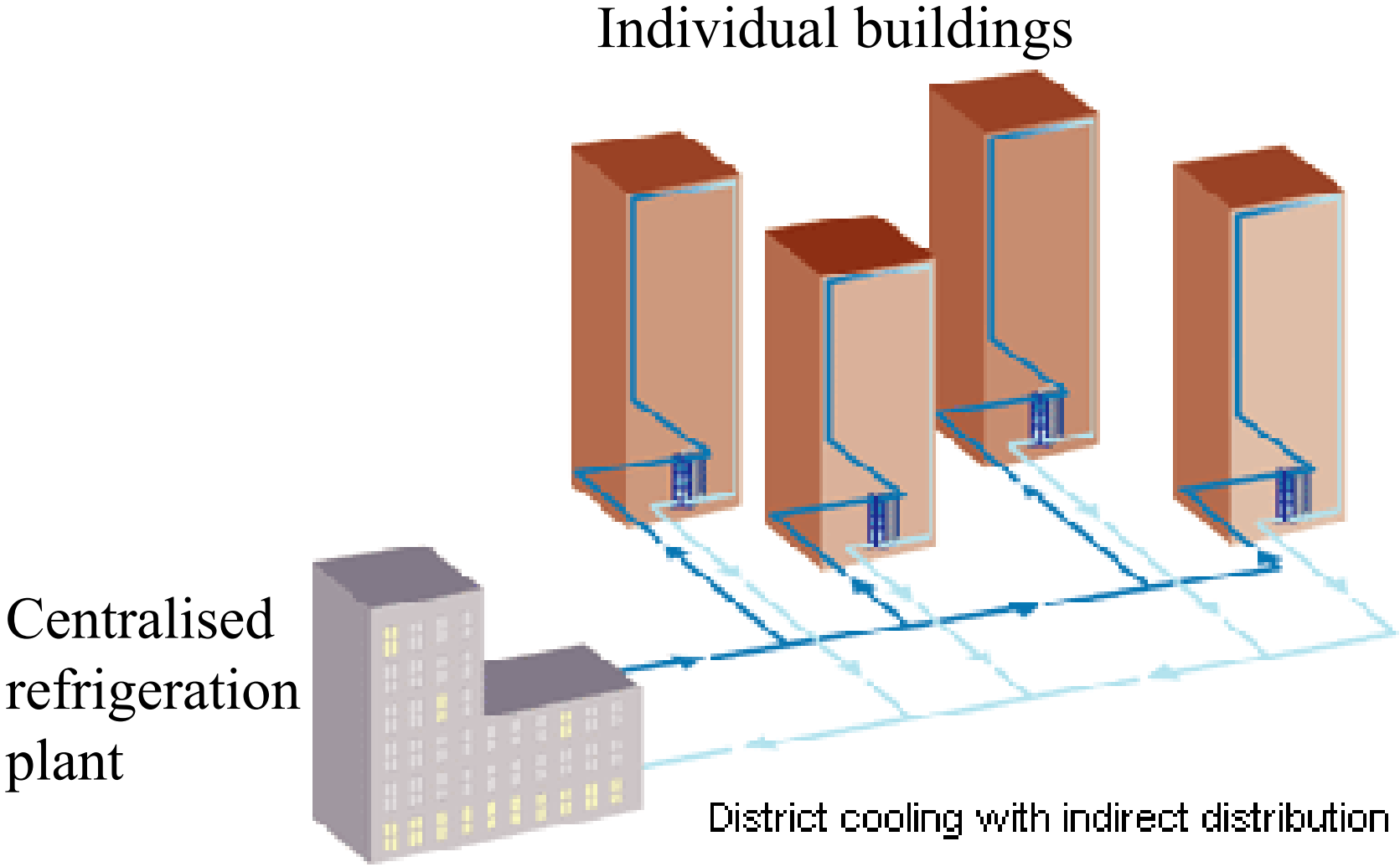
(a) Air-side economiser cycle
- intake more outdoor air when its enthalpy (energy content) is lower than indoor air

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

'Free' cooling methods in HVAC system



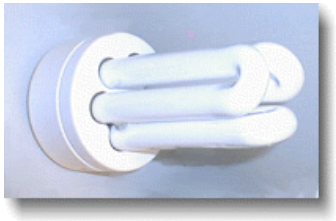
Waste heat recovery - heat pump + chiller



District cooling system

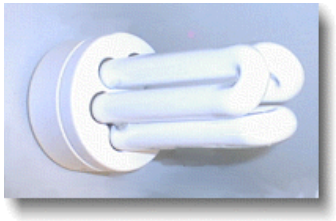
(Question: Do you know what are the advantages?)

Energy Efficiency

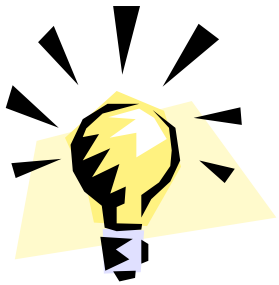


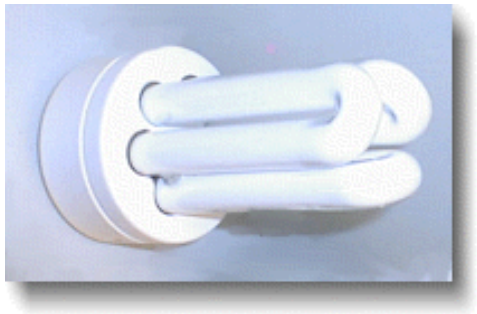
- HVAC energy efficiency can be improved by:
  - Effective zoning and space design
  - Correct sizing and selection of equipment
  - Proper operation and maintenance
  - Better control and monitoring
  - Energy awareness of occupants/building managers
- Good house-keeping and education
  - A very important factor which is often overlooked

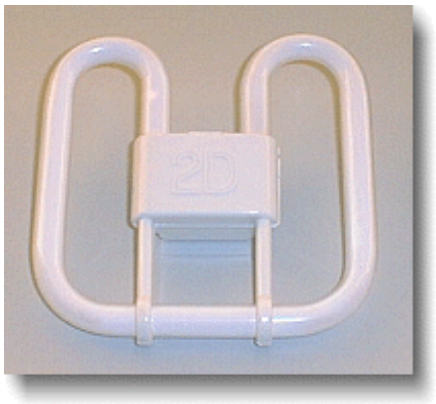
Energy Efficiency



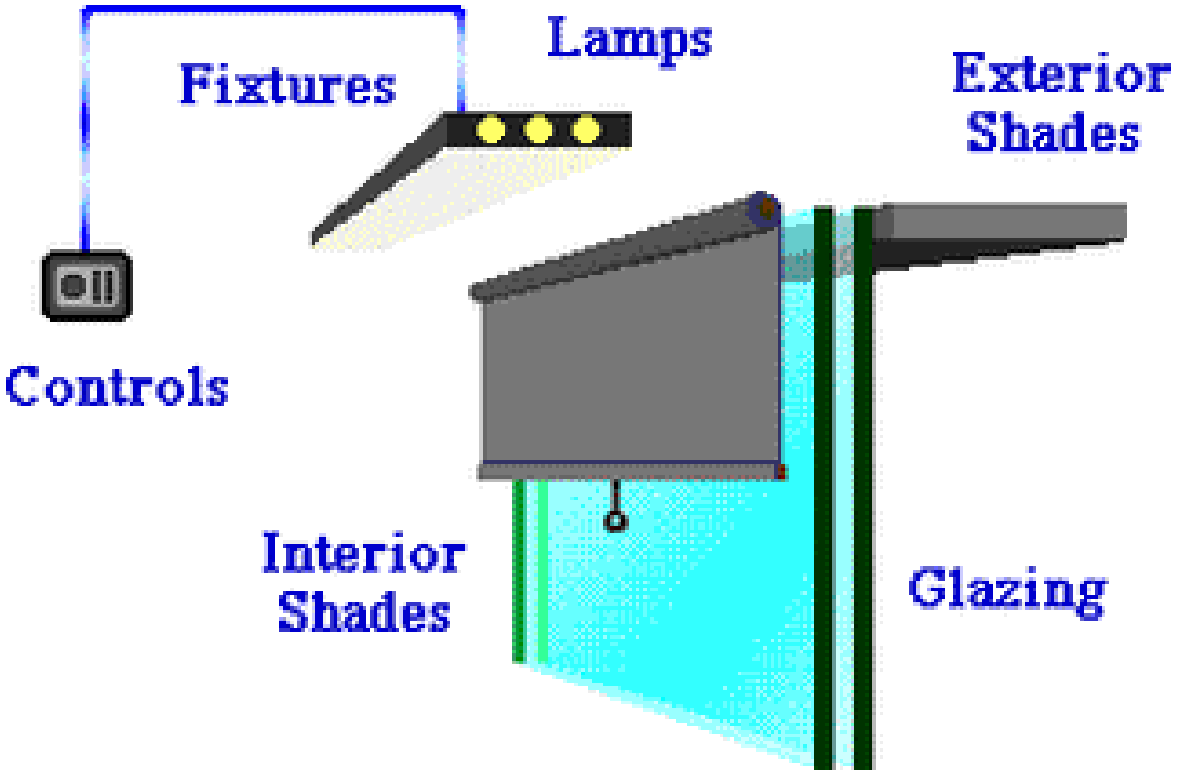
- Lighting systems
  - Have good potential for conserving electricity
  - Also contribute to HVAC load reduction
- General principles of energy efficient lighting
  - Illumination is not excessive
  - Switching arrangements are designed
  - Provide illumination in an efficient manner



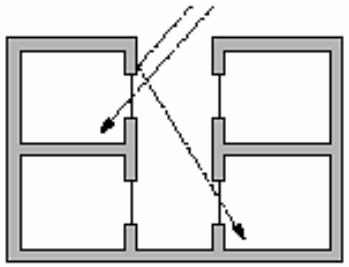




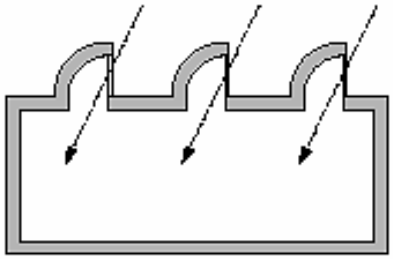
Energy efficient fittings (e.g. compact fluorescent lamps)



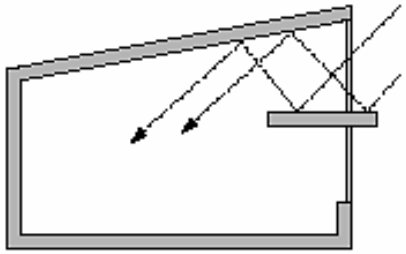
Lighting controls and interactions with windows



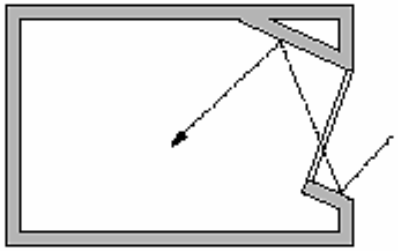
Light well



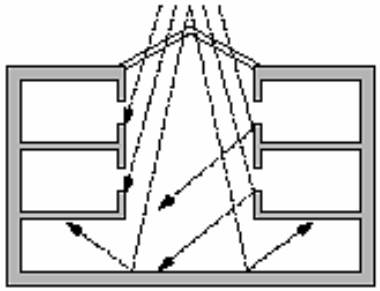
Roof monitor



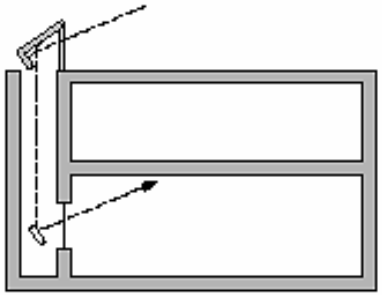
Light shelf



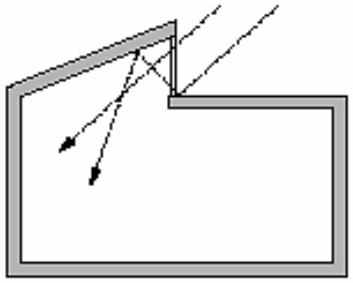
External reflectors



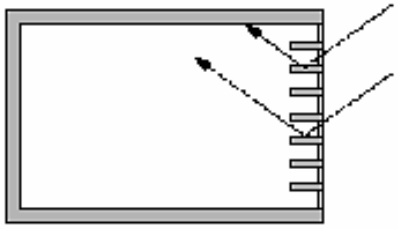
Atrium



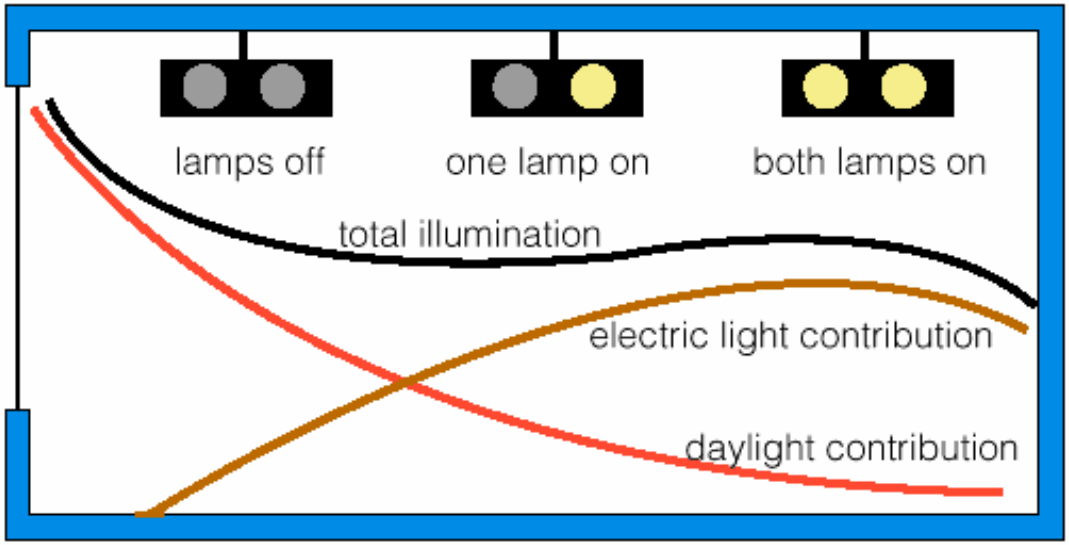
Light duct



Clerestory

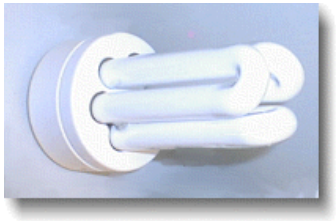


Reflective blinds

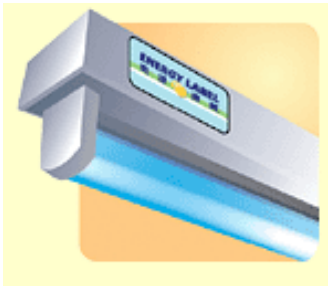


Daylighting design and control

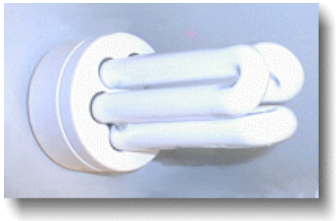
Energy Efficiency



- Conserve lighting energy by:
- (a) Reduce power input
  - Illumination level required, lamp types, ballast, room layouts and colours
- (b) Reduce hours of use
  - Optimised switching
  - Automatic controls
  - Use of daylight
  - Education and propaganda



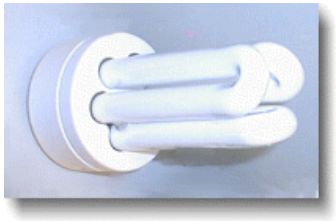
Energy Efficiency



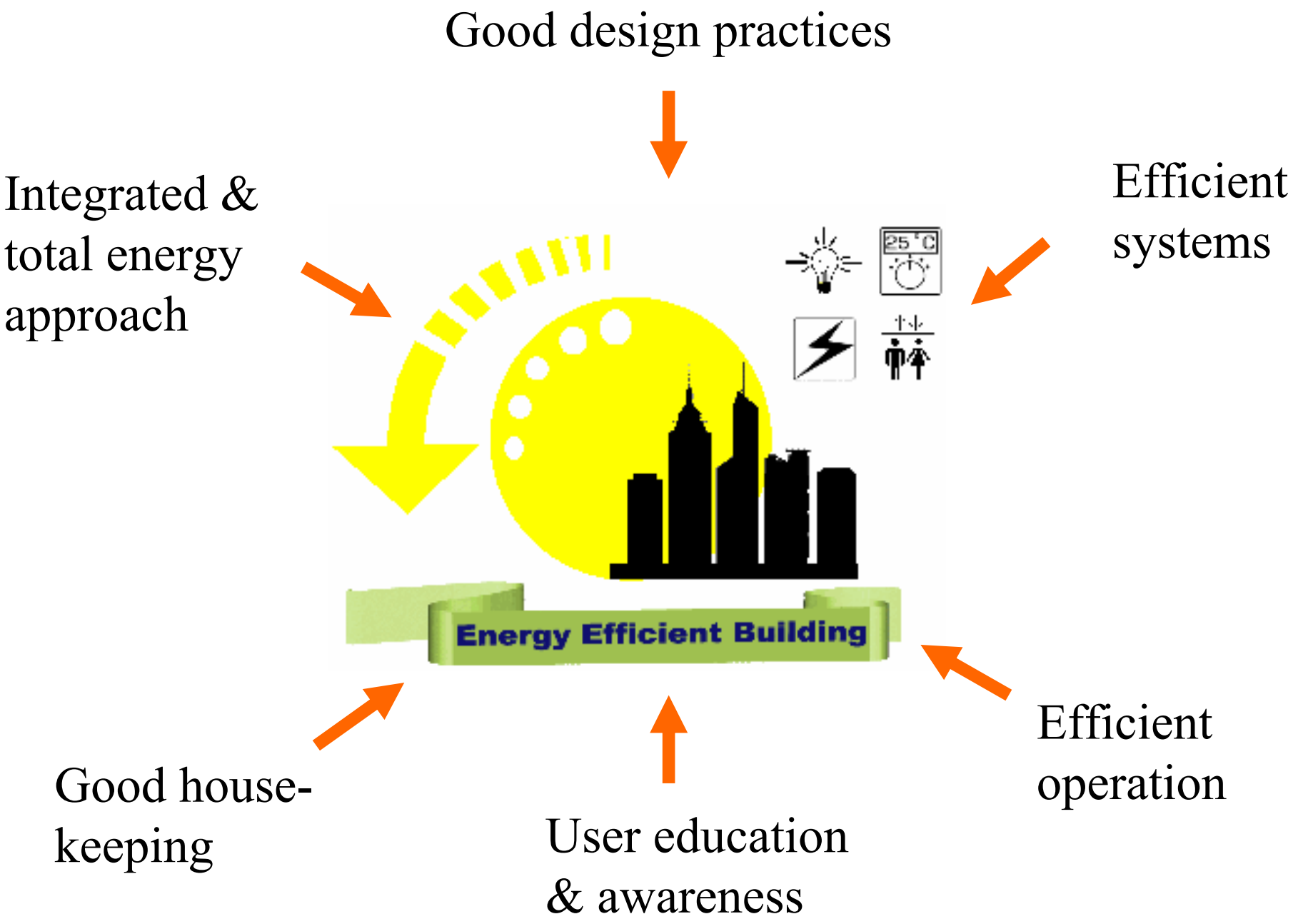
- Other building services systems
  - Electrical installation
  - Lifts and escalators
  - Water supply systems
  - Town gas supply system (cooking)

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

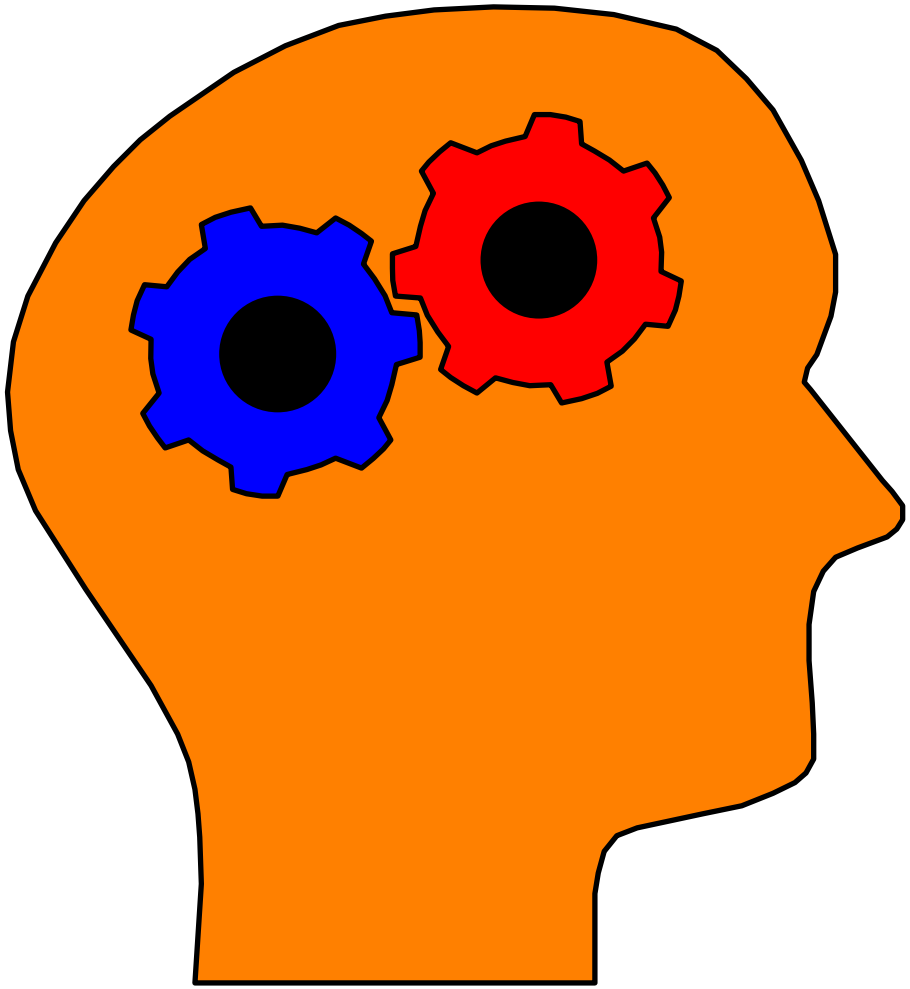
Energy Efficiency



- Human factors
  - Comfort requirements
    - Thermal comfort
    - Visual comfort
    - Noise control
  - Occupant behaviours
    - Patterns of use
    - Periods of occupation
- Management issues
  - Building use, operation & maintenance


Good design practices
Integrated & total energy approach
Efficient systems
25 °C
Energy Efficient Building
Good house-keeping
User education & awareness
Efficient operation

QUIZ



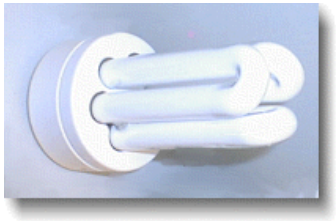
The average prices (HK$) of electricity and towngas in Hong Kong are (Year 2007):

A. Elec. = $1.0/kWh (CLP) Towngas = $0.25/MJ	B. Elec. = $2.0/kWh (CLP) Towngas = $0.11/MJ
C. Elec. = $2.0/kWh (CLP) Towngas = $0.25/MJ	D. Elec. = $1.0/kWh (CLP) Towngas = $0.11/MJ

Replace a 60 W incandescent light bulb with a 9 W compact fluorescent lamp (energy saving lamp) will generate how much electrical energy saving?

A. 75%	B. 80%
C. 85%	D. 90%

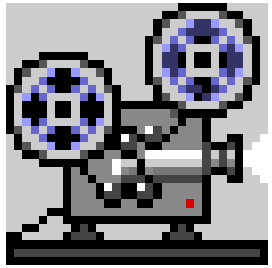
Energy Efficiency



- Checklist for Energy Efficiency
  - http://arch.hku.hk/~cmhui/teach/SBT/check.pdf
    - Architecture
    - HVAC
    - Electrical services
    - Lighting installations
    - Lifts and escalators
    - Plumbing and drainage
    - Building management

Energy saving in lift system

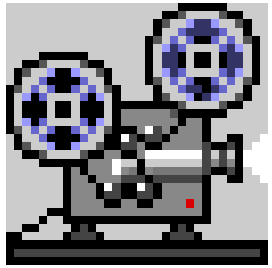
Video Presentation



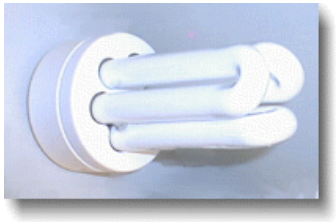
- The Story of Lang (晴朗的天空) [16 min.]
  - A journey to the world of energy efficiency
  - This is the story of Lang, a journalist, who learns that saving energy not only saves money, but also makes the world a better place for our community and future generations to live in. He also learns that big energy savings begin with small things in life.

This video can also be viewed at:
http://www.energyland.emsd.gov.hk/eng/useful/story_of_lang_bb.htm

Video Presentation



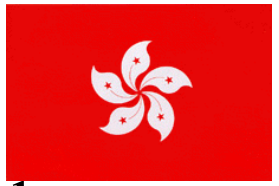
- Discussions: Leading questions
  - What are the benefits of energy saving?
  - What are energy efficiency labels?
  - What are the energy efficient technologies used in the HK International Airport?
  - What are the major energy uses in households?
  - Why some people are not aware of energy saving?
  - How to change the people's wasteful behaviours?



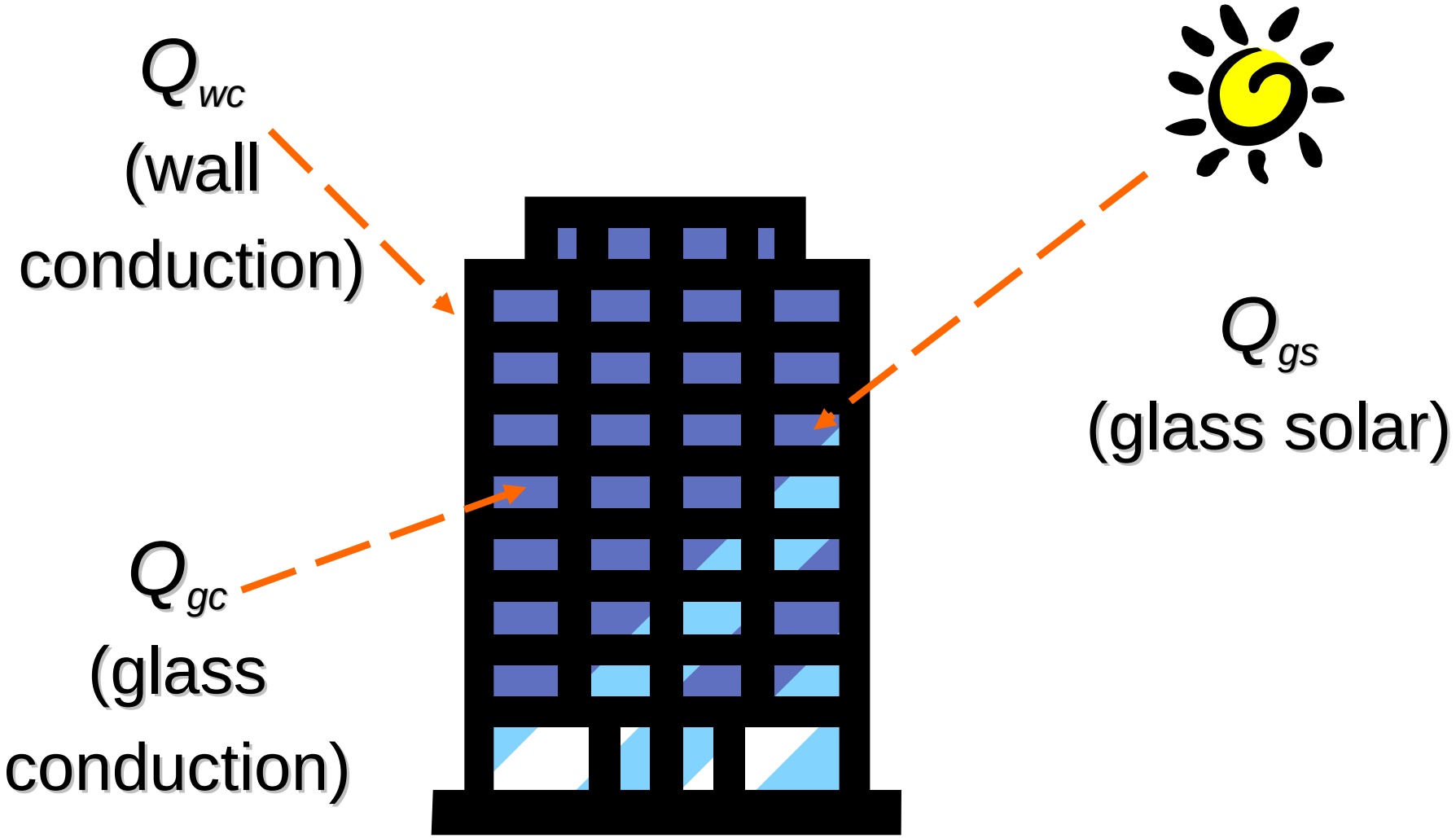
Energy Policy and Codes

- Building Energy Codes (*BEC*)
  - Set out energy consumption objectives
  - Form part of the energy policy
  - Control building design and/or operation
- Energy audit requirements (in some countries)
  - Essential for existing buildings
- Energy management programmes
  - Promote good practices in design and operation

Energy Policy and Codes



- First energy efficiency regulation in HK
  - *Building (Energy Efficiency) Regulation*, Cap. 123 sub. Leg. M [implemented in July 1995]
    - http://arch.hku.hk/research/BEER/bee-reg.htm
  - Using Overall Thermal Transfer Value (OTTV) method for building envelope design control
    - www.bd.gov.hk/english/documents/code/e_ottv.htm
  - Applied mainly to commercial buildings and hotels; requirements revised in 2000
    - Building tower: OTTV $\leq$ 30 W/m^2; podium: OTTV $\leq$ 70 W/m^2



$$OTTV_i = \frac{Q_{wc} + Q_{gc} + Q_{gs}}{A_i}$$

$$= \frac{(A_w \cdot U_w \cdot TD_{eq}) + (A_f \cdot U_f \cdot DT) + (A_f \cdot SC \cdot SF)}{A_i}$$

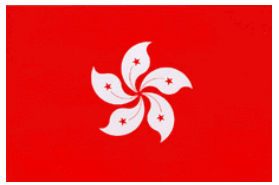
Energy Policy and Codes

- OTTV equation for Hong Kong:

$$OTTV_i = \frac{(A_w \cdot U_w \cdot \alpha \cdot TD_{eq}) + (A_f \cdot SC \cdot ESM \cdot SF)}{A_i}$$

- Two major differences from the general form:
  - Glass conduction term was omitted
  - Solar absorptivity and external shading multipler were introduced

Energy Policy and Codes



- HK building energy codes (voluntary)
  - Lighting
  - Air-conditioning
  - Electrical
  - Lifts & escalators
  - Performance-based code

- Put under the Hong Kong Energy Efficient Building Registration Scheme (HKEEBRS)
  - Will become mandatory soon

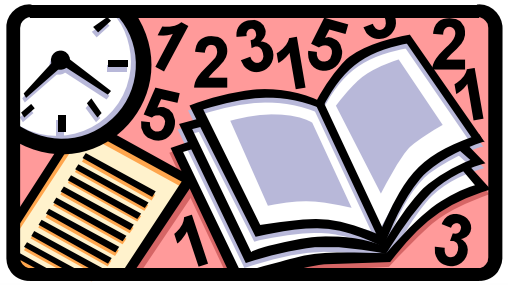
Building Energy Codes in Hong Kong

(Source: www.emsd.gov.hk)

Building energy codes in Hong Kong

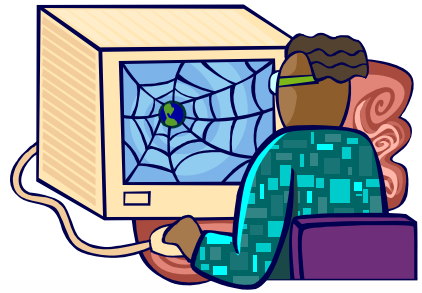
Energy Code	Date Implemented	Scope
OTTV	Jul 1995 (Mandatory)	Comm bldgs & hotels
Lighting	Jul 1998 (Voluntary)	All bldgs except domestic, indust. & medical
Air conditioning	Jul 1998 (Voluntary)	All bldgs except domestic, indust. & medical
Electrical	Feb 1999 (Voluntary)	All buildings
Lifts & escalators	Dec 1999 (Voluntary)	All buildings
Performance-based code	2004 (Voluntary)	Comm bldgs & hotels

Useful Guidebooks



- EMSD, 2005. *Energy Efficiency and Conservation for Buildings*, Energy Efficiency Office, Electrical and Mechanical Services Department, Hong Kong.
  - http://www.emsd.gov.hk/emsd/e_download/pee/emsd100dpi.pdf
- CIBSE, 2004. *Energy Efficiency in Buildings: CIBSE Guide F*, 2nd edition, Chartered Institution of Building Services Engineers, London.

Useful Websites



- EnergyLand, Electrical and Mechanical Services Department (EMSD), www.energyland.emsd.gov.hk
- HK Sustainable Technology Net, http://sustech.emsd.gov.hk/
  - HK RE Net, http://re.emsd.gov.hk/
  - HK EE Net, http://ee.emsd.gov.hk
  - HK Green Building Technology Net, http://gbtech.emsd.gov.hk