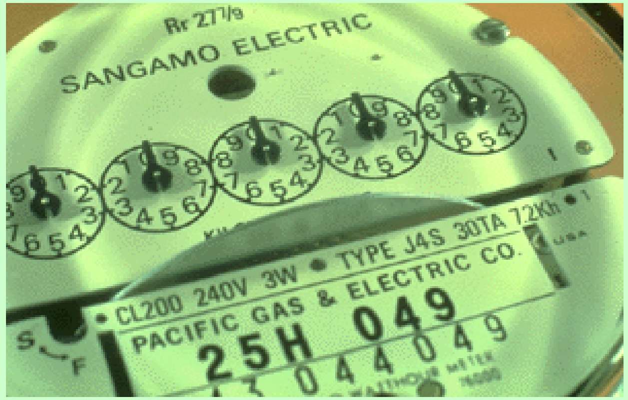
SBS5421 Building Energy Efficiency cum Carbon Emission

http://ibse.hk/SBS5421/



Introduction

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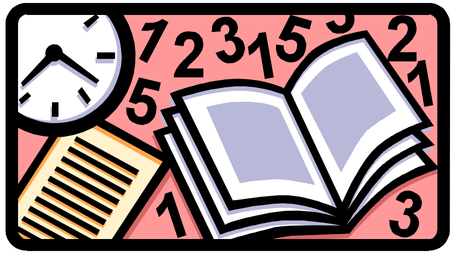
Dec 2018

Contents

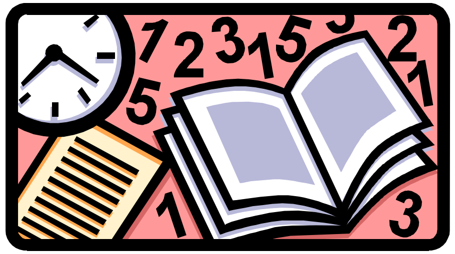
- Background
- Energy Basics
- Energy Use in Buildings
- Energy Efficiency
- Building Services Systems

Background

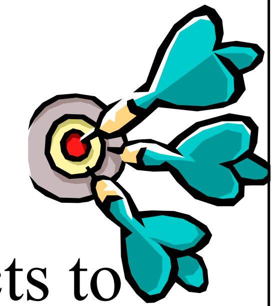


- <u>Module Aim(s)</u>:
  - The module aims to provide students with an overview of energy use patterns in buildings and understanding of the energy audit and survey process. It also enables students to master various building performance assessment methods as to management and carry out building energy performance upgrading projects.

Background

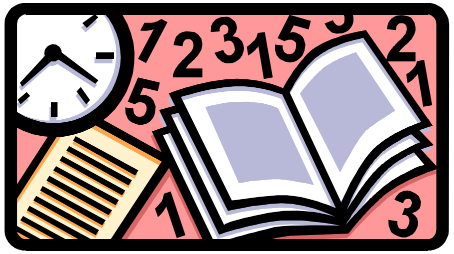


- <u>Learning Outcomes</u>:



  - 1. identify the energy use patterns in various types of buildings and the major energy end-uses, and its impacts to environment of building energy uses;
  - 2. conduct energy audits and surveys based on established guideline, identify and implement energy management opportunities (EMO) and using suitable instrumentations;
  - 3. apply building energy management principles to maximise the energy saving in buildings;
  - 4. assess the building energy performance in various buildings to define energy performance benchmarks; and
  - 5. implement energy performance upgrading projects in buildings.

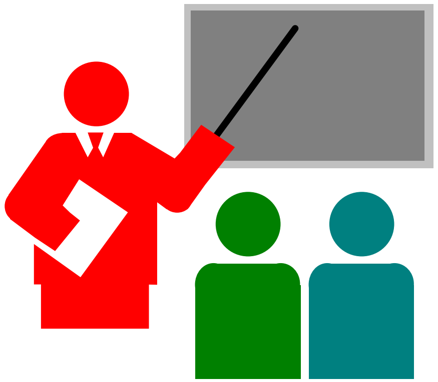
Background



- Lecturers:
  - Ir Dr. Sam C. M. Hui (cmhui@vtc.edu.hk)
  - Dr. PAN Yan, Penny (pennypan@vtc.edu.hk)
- Course Website: (with links and resources)
  - http://ibse.hk/SBS5421/
- Moodle system
  - http://moodle.thei.edu.hk/

Dr. Hui

Dr. Pan



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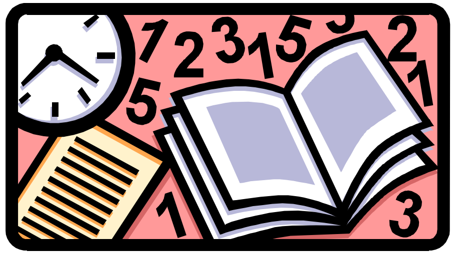
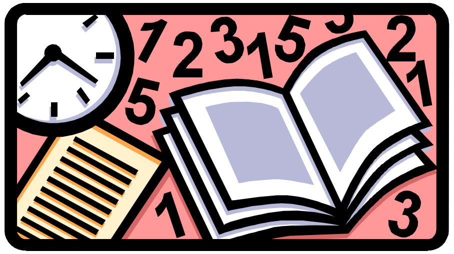


- Assessment Components:
- Project (40%):
  - Interim Report (10%)
  - Oral Presentation (10%)
  - Final Report (20%)
- Examination (60%) (3 hours)
  - Section A by Dr. Hui (5 out of 6 questions @ 10 marks)
  - Section B by Dr. Pan (5 out of 6 questions @ 10 marks)

Background



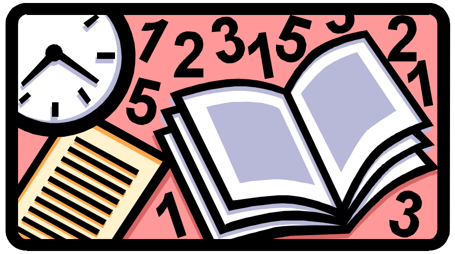
- Study topics:
  - 1. Introduction
  - 2. Building energy performance
  - 3. Building energy design and management
  - 4. Building energy audit and survey
  - 5. Energy information system and data analysis

Dr. Hui

  - 6. Energy efficient technologies (I & II)
  - 7. Building energy standards and codes (I & II)
  - 8. Building energy simulation (I & II)

Dr. Pan

Background



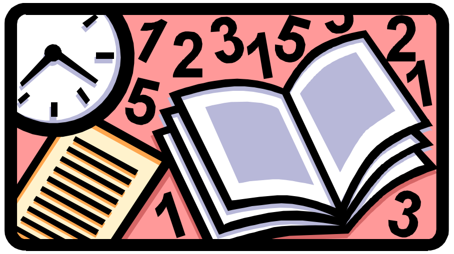
- ***Ir. Dr. Sam C. M. Hui*** (*Building Services Engineer*)

  - PhD, BEng(Hons), CEng, CEM, BEAP, BEMP, HBDP, MASHRAE, MCIBSE, MHKIE, MIESNA, LifeMAEE, AssocAIA
    - CEng = Chartered Engineer

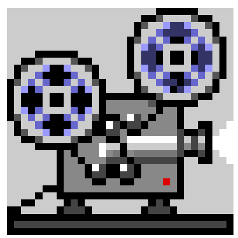
    Energy-related qualifications

    - CEM = Certified Energy Manager
    - BEAP = Building Energy Assessment Professional
    - BEMP = Building Energy Modeling Professional
    - HBDP = High-performance Building Design Professional
    - LifeMAEE = Life Member, Association of Energy Engineers
  - ASHRAE Distinguished Lecturer (2009-2011)
  - 20 yrs. teaching in HKU Departments of Architecture and Mech. Engg.
  - Research interests: energy efficiency in buildings and sustainable building technologies

Background



- Learning Methods:
  - Lectures + Further reading
  - Project-based learning
  - Technical seminars
- Resources:
  - Videos + ebooks
  - Web links + References



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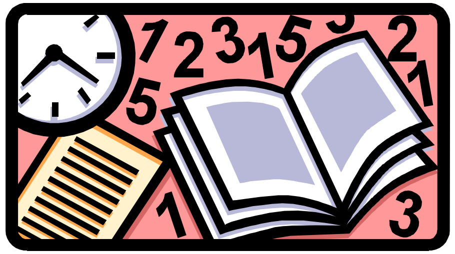
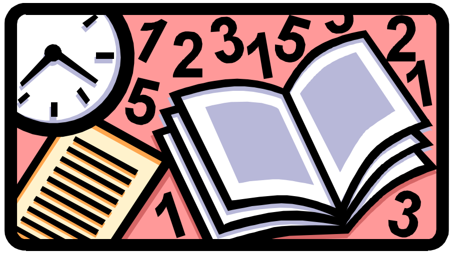


- Useful References:

  - CIBSE, 2012. *Energy Efficiency in Buildings: CIBSE Guide F*, 3rd edition, Chartered Institution of Building Services Engineers, London.
  - EMSD, 2018. *Code of Practice for Energy Efficiency of Building Services Installation*, Electrical and Mechanical Services Department, Hong Kong.
  - EMSD, 2018. *Code of Practice for Building Energy Audit*, Electrical and Mechanical Services Department, Hong Kong.
  - EMSD, 2015. *Technical Guidelines on Code of Practice for Energy Efficiency of Building Services Installation*, Electrical and Mechanical Services Department, Hong Kong.
  - EMSD, 2015. *Technical Guidelines on Code of Practice for Building Energy Audit*, Electrical and Mechanical Services Department, Hong Kong.

Background



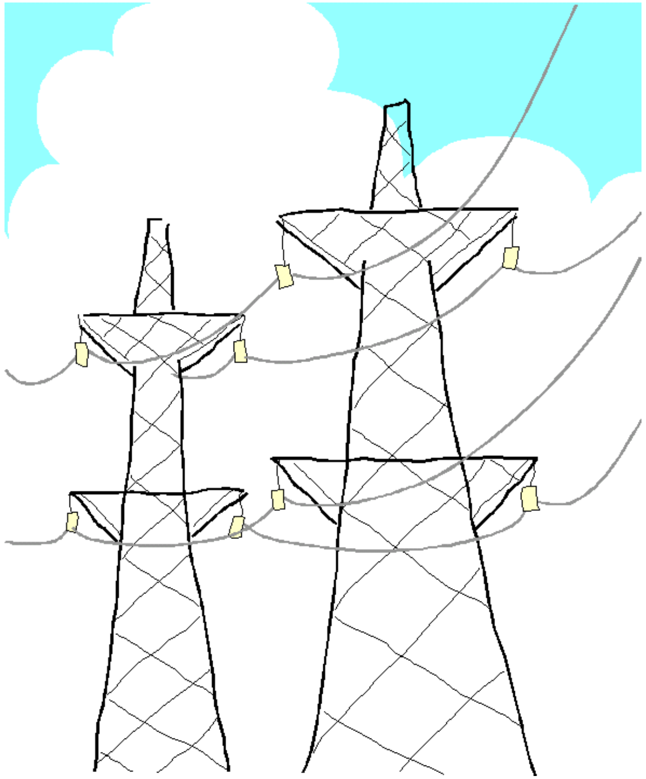
- Useful Websites:
  - Buildings Energy Efficiency Ordinance (Cap. 610) [EMSD] https://www.emsd.gov.hk/beeo/
  - Energy Land [EMSD] https://www.emsd.gov.hk/energyland/
  - HK EE Net 香港節能網 http://ee.emsd.gov.hk/
  - HK RE Net 香港可再生能源網 http://re.emsd.gov.hk/

Energy Basics

- Units of energy*
  - Kilowatt-hour (kWh), 1 kWh = 3.6 x 10^6 joule
    - 1 kWh = 3.6 MJ = 860 kcal = 3412 Btu
  - Calorie (卡路里), 1 calorie (cal) = 4.2 x 10^3 J
  - British thermal unit (Btu), 1 Btu = 1.055 x 10^3 J
  - Therme (gas supply), 1 therme = 100 000 Btu
  - Tonne of oil equivalent (toe) (from oil industry)
    - 1 toe = 4.2 x 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

(*See also http://www.aps.org/policy/reports/popa-reports/energy/units.cfm)

能源



Energy Basics

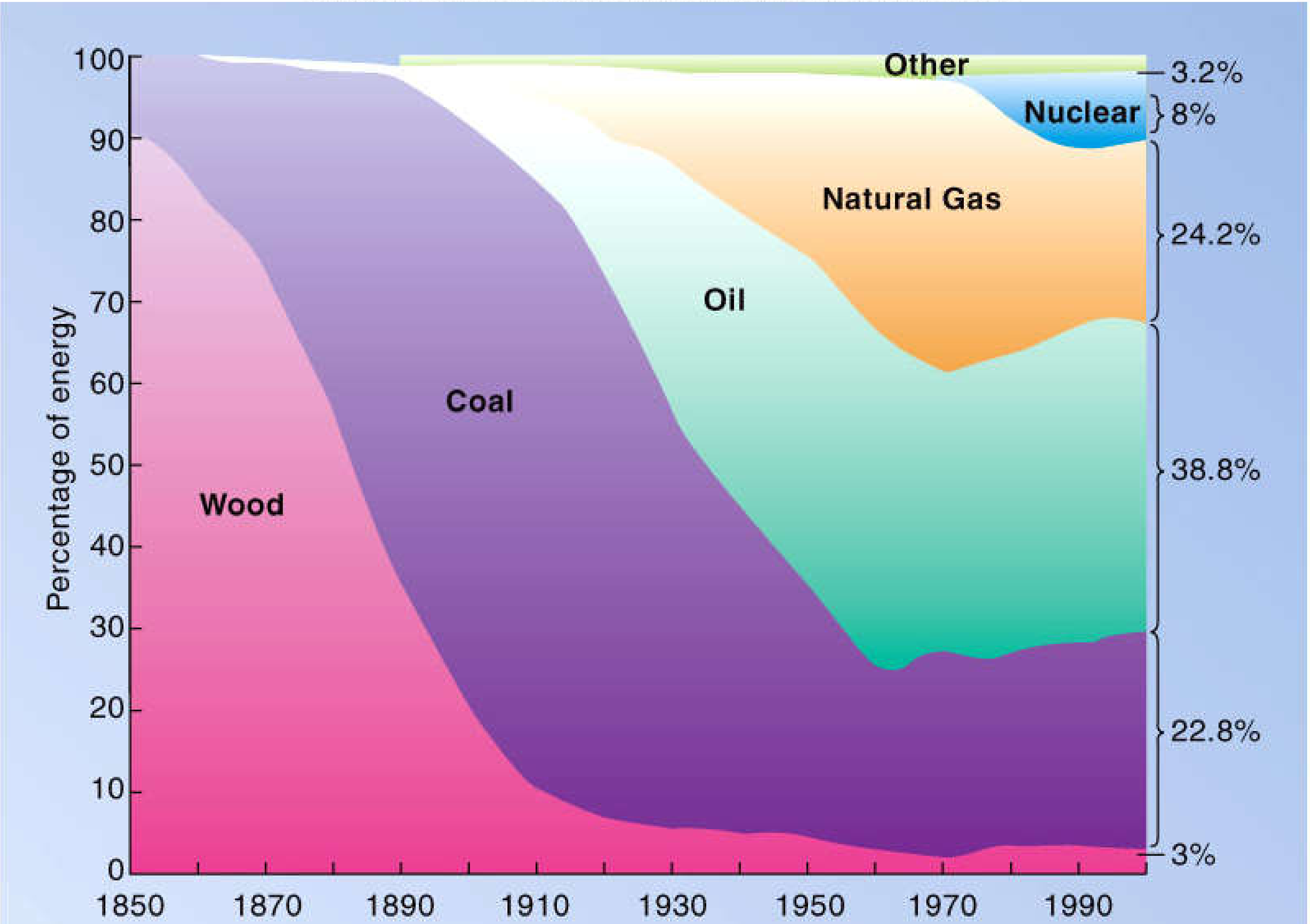
- Forms of energy: (*Supply side, primary energy*)
  - **Electricity** (most important)*
  - Natural gas, town gas, liquified petroleum gas (LPG)
  - Oil products
  - Coal
  - Hydropower
  - Renewable energy (e.g. solar, wind)
  - Nuclear energy

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

Energy Basics

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

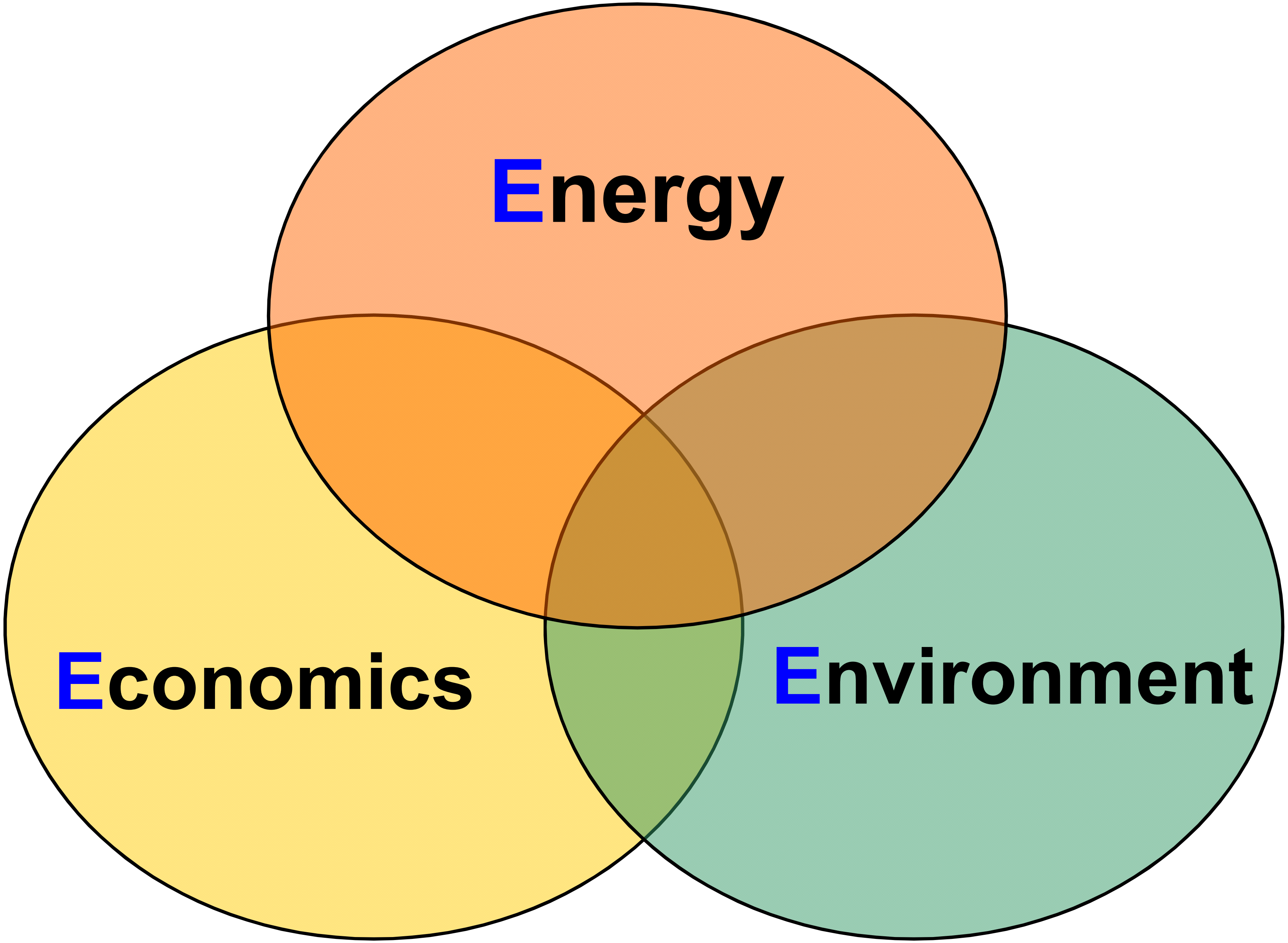
Changes in Energy Sources in Year 1850-2000



Energy Basics

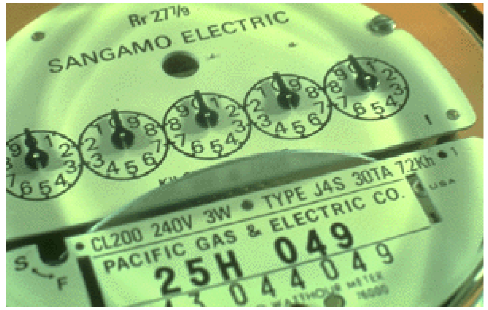
- **Energy** is important to every society
  - Economic, environmental & social impacts
  - It is also a key issue for ***sustainable development***
- Use energy …
  - Consume finite fossil fuels (oil, coal, natural gas)
  - Cause air pollution & environmental damage
  - Contribute to global warming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

3 'E' Relationships

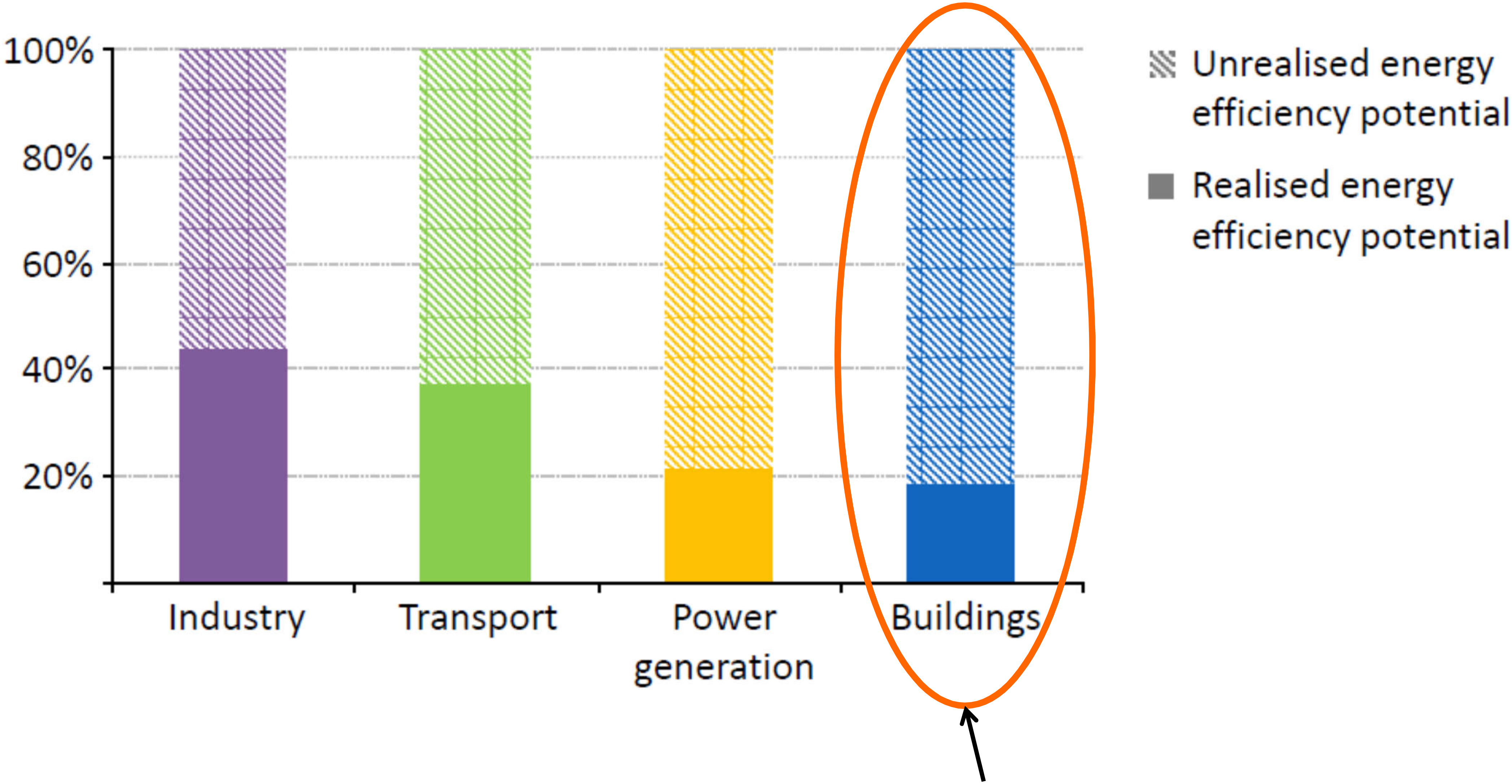


Energy Basics

- Significance of energy management
  - 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 efficiency potential used by sector: a huge opportunity going unrealised



The building sector has the largest potential

(Source: Fatih Birol, Chief Economist, International Energy Agency, www.iea.org)

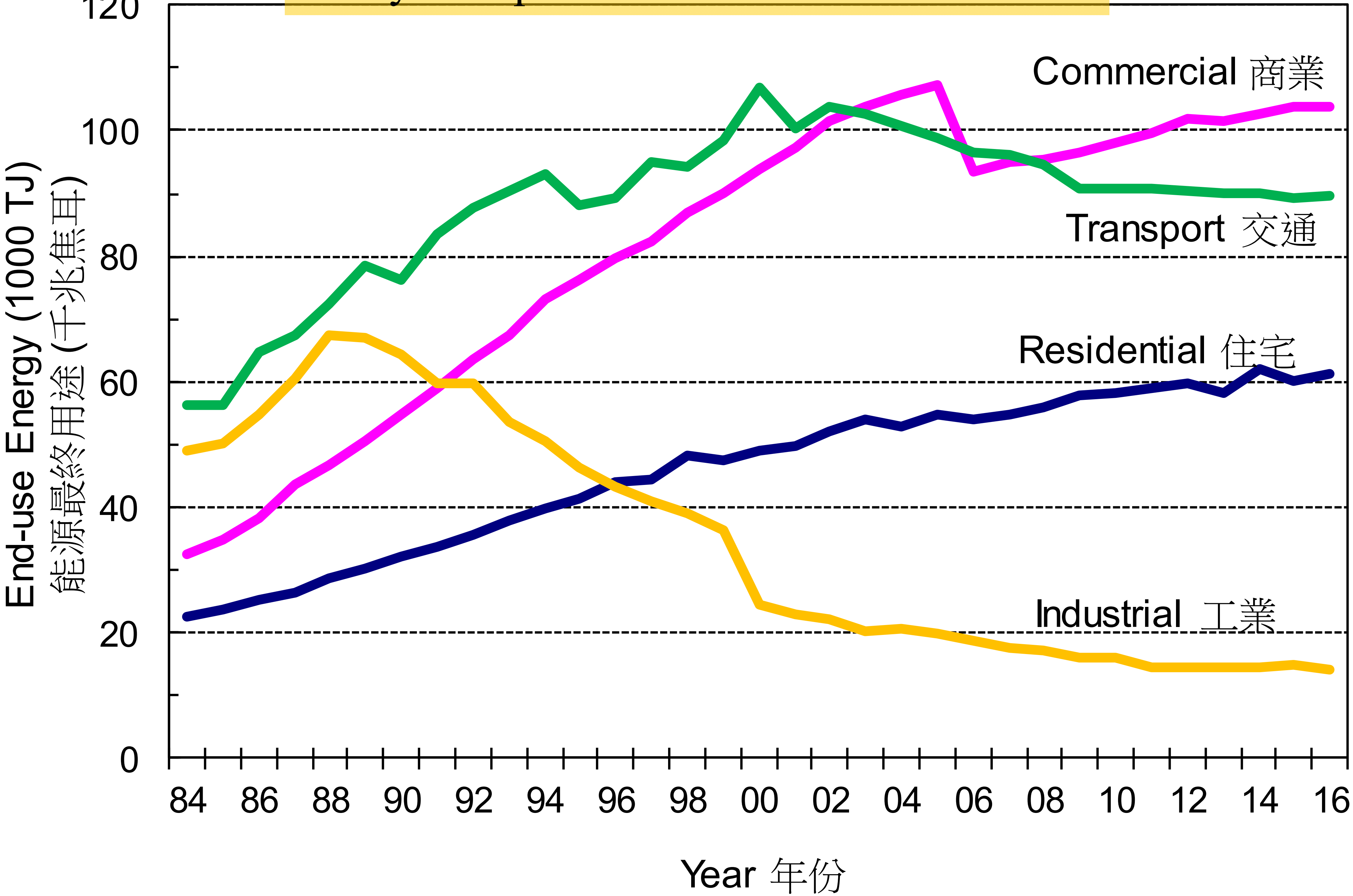
Energy Use in Buildings

- About 90% of total electricity consumption in Hong Kong is contributed by 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 (e.g. $$ for pollution control & “repairing” of environmental damages)

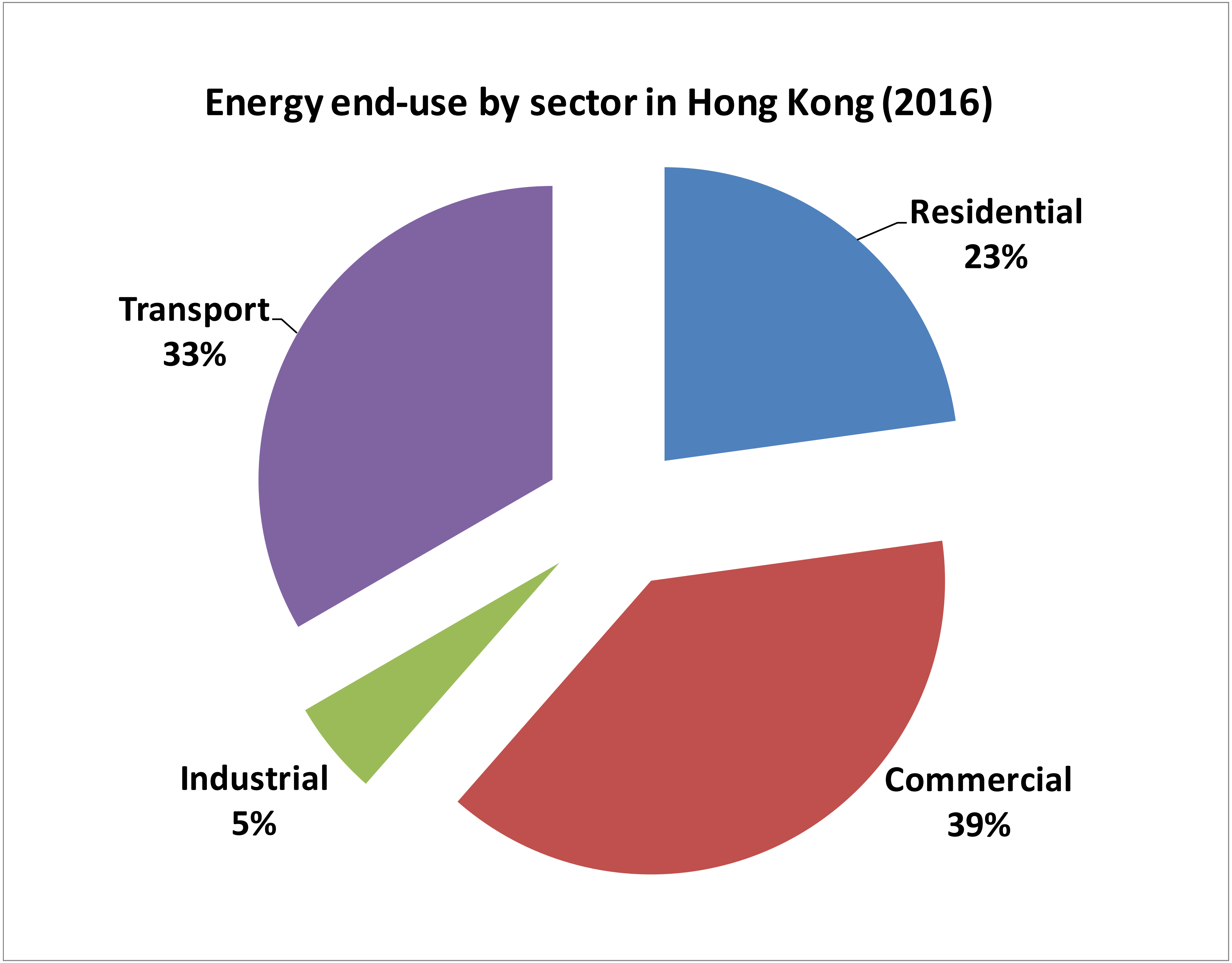
Energy Use in Buildings

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

Can you explain the trends of each sector?



(Data source: EMSD) Energy end-use in Hong Kong by sectors, 1984-2016



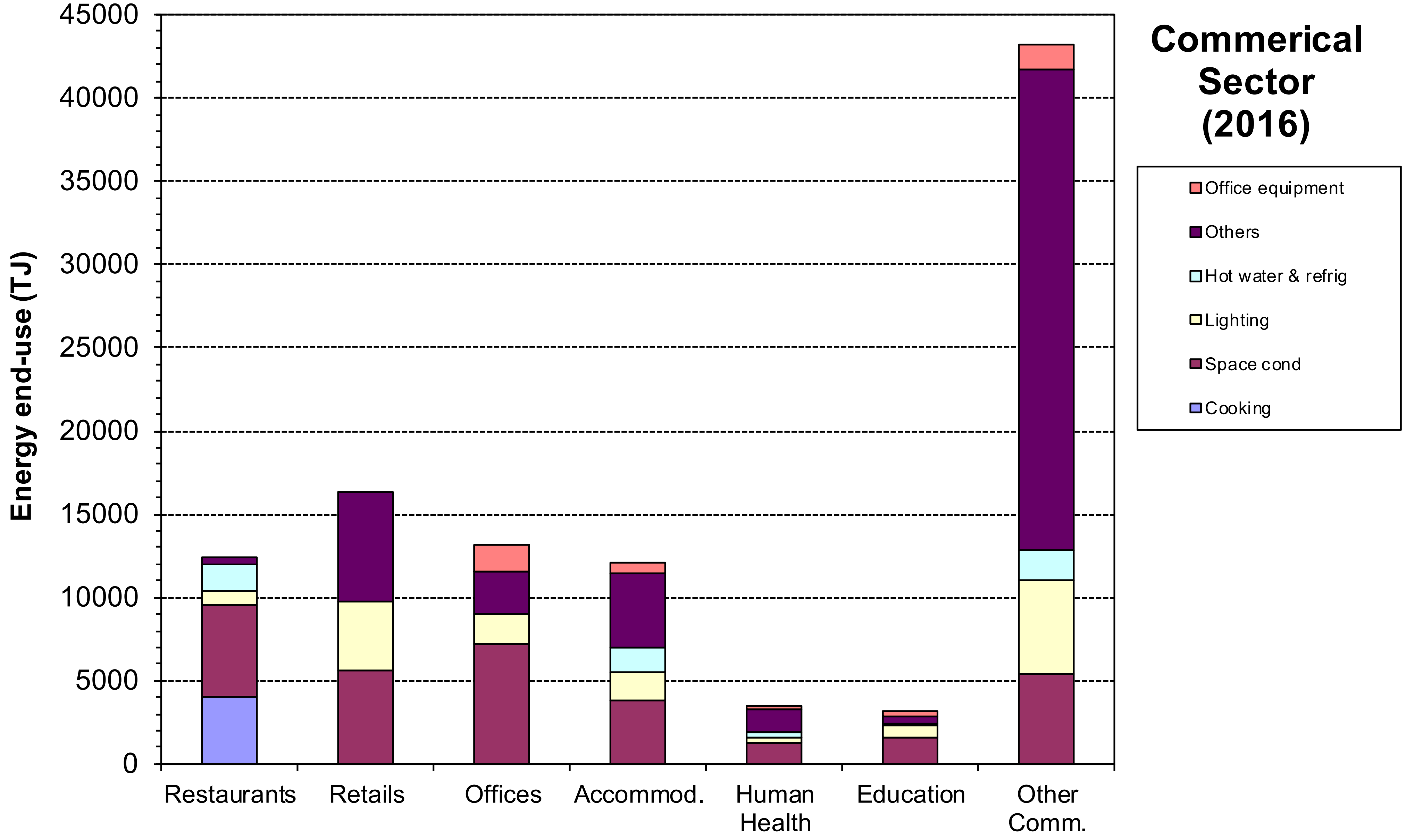
(Data source: EMSD)

Table 1 - Final energy requirements (FER) in Hong Kong (year 2017)

Unit: MJ	**Commercial**	**Residential**	**Industrial**	**Total**
Electricity	104 281 (66%)	42 127 (27%)	11 196 (7%)	157 604 (100%)
Town gas	12 161 (42%)	15 319 (53%)	1 569 (5%)	29 049 (100%)
Elec. + town gas	116 442	57 446	12 765	186 653
% in total FER	34.4%	17.0%	3.8%	55.2%

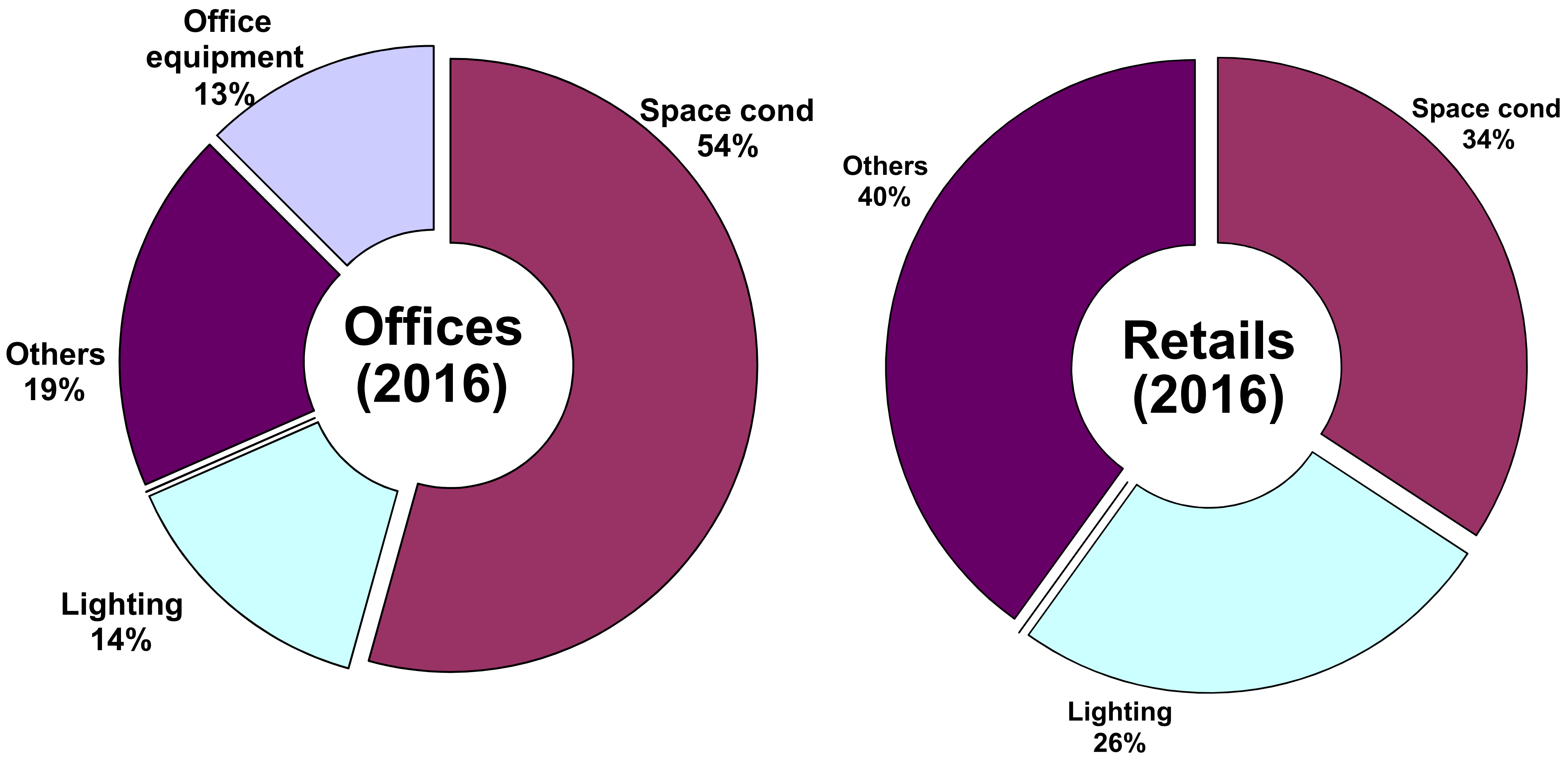
Total FER for 2017 = 338 264 TJ

(* Data Source: *Hong Kong Energy Statistics 2017 Annual Report*)



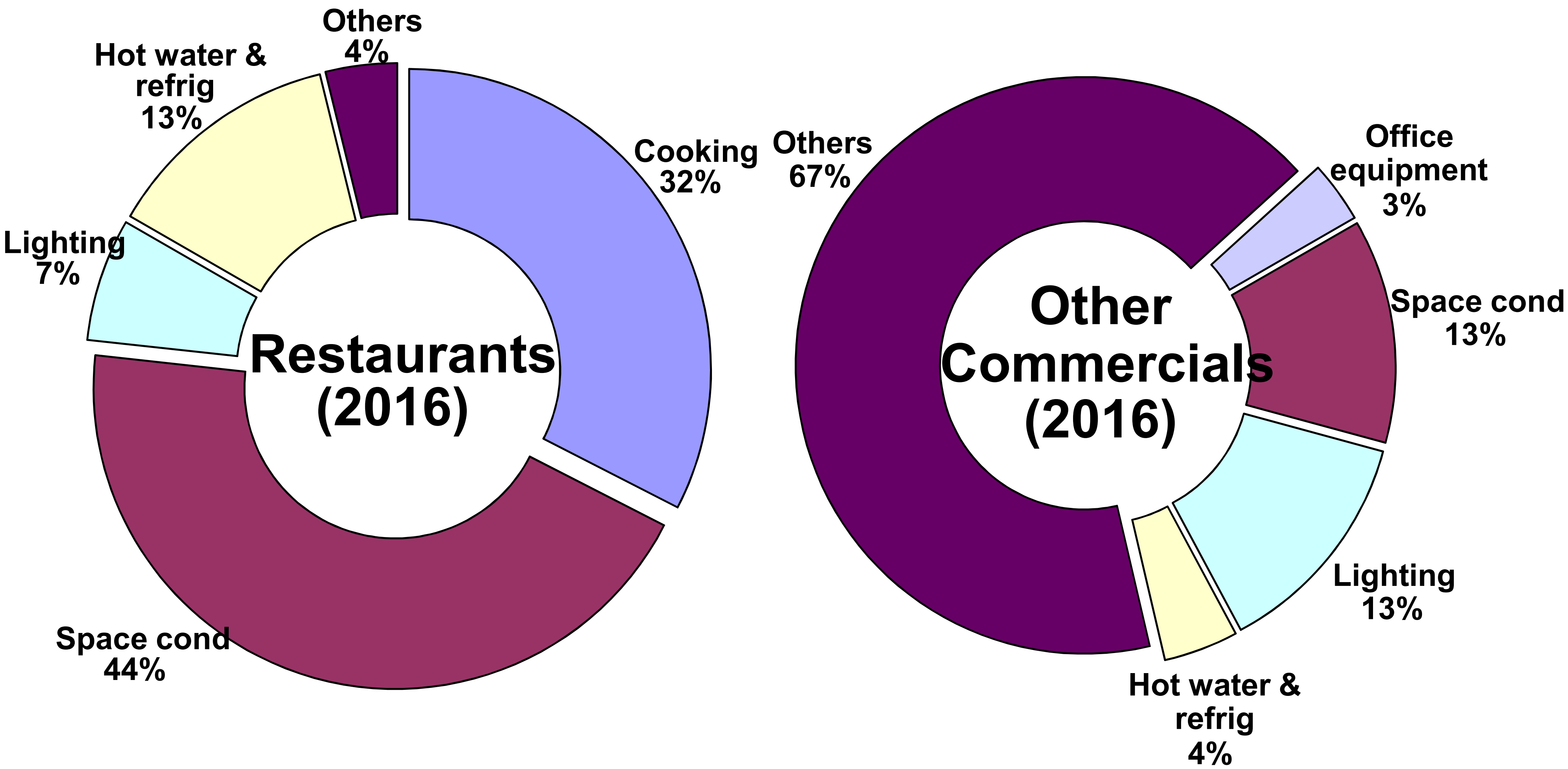
Energy end-use in commercial sector, 2016
(Data source: Energy Efficiency Office, HK)

What are the major energy usages?

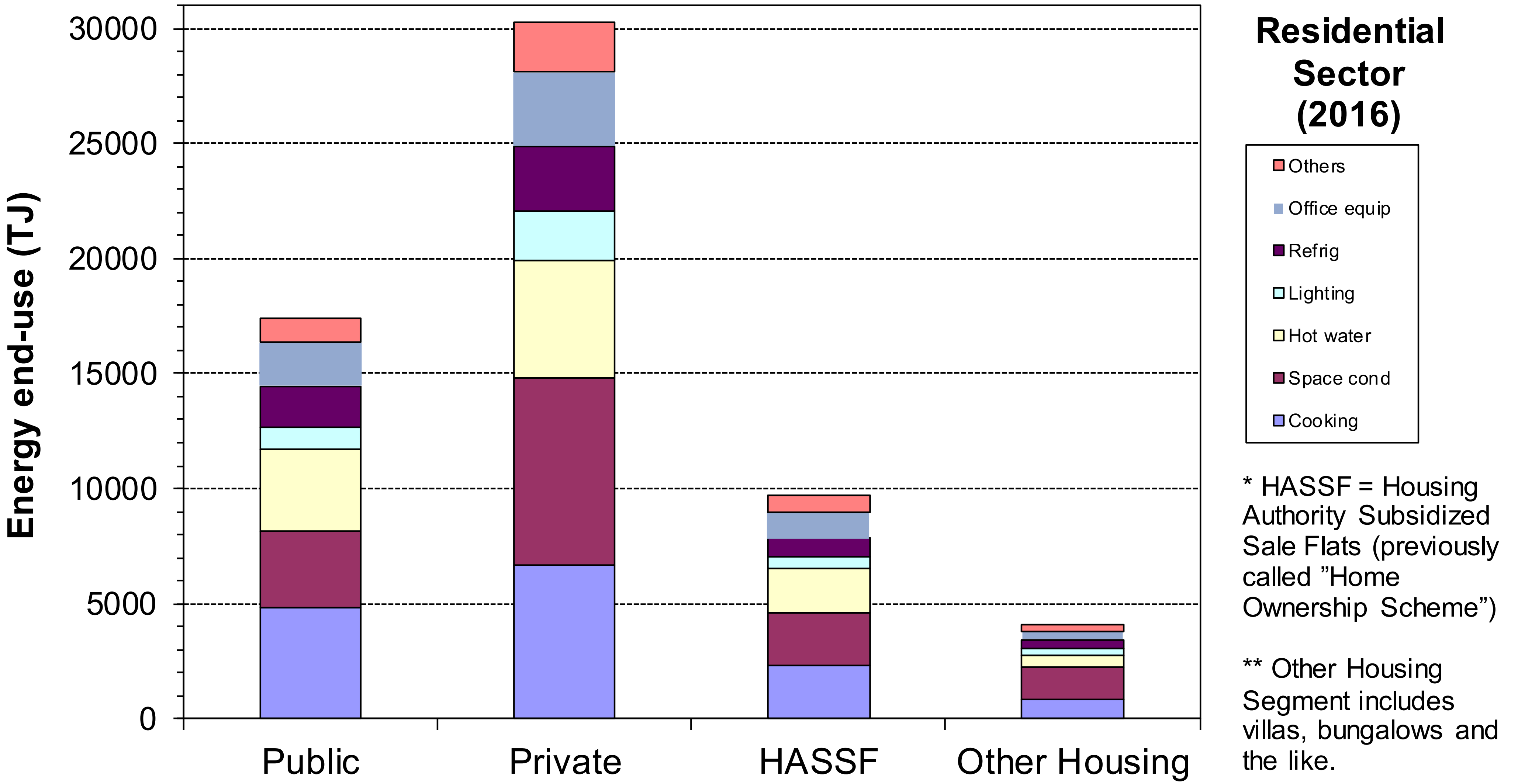


Energy consumption patterns in offices and retails
(Data source: Energy Efficiency Office, HK)

What are the major energy usages?

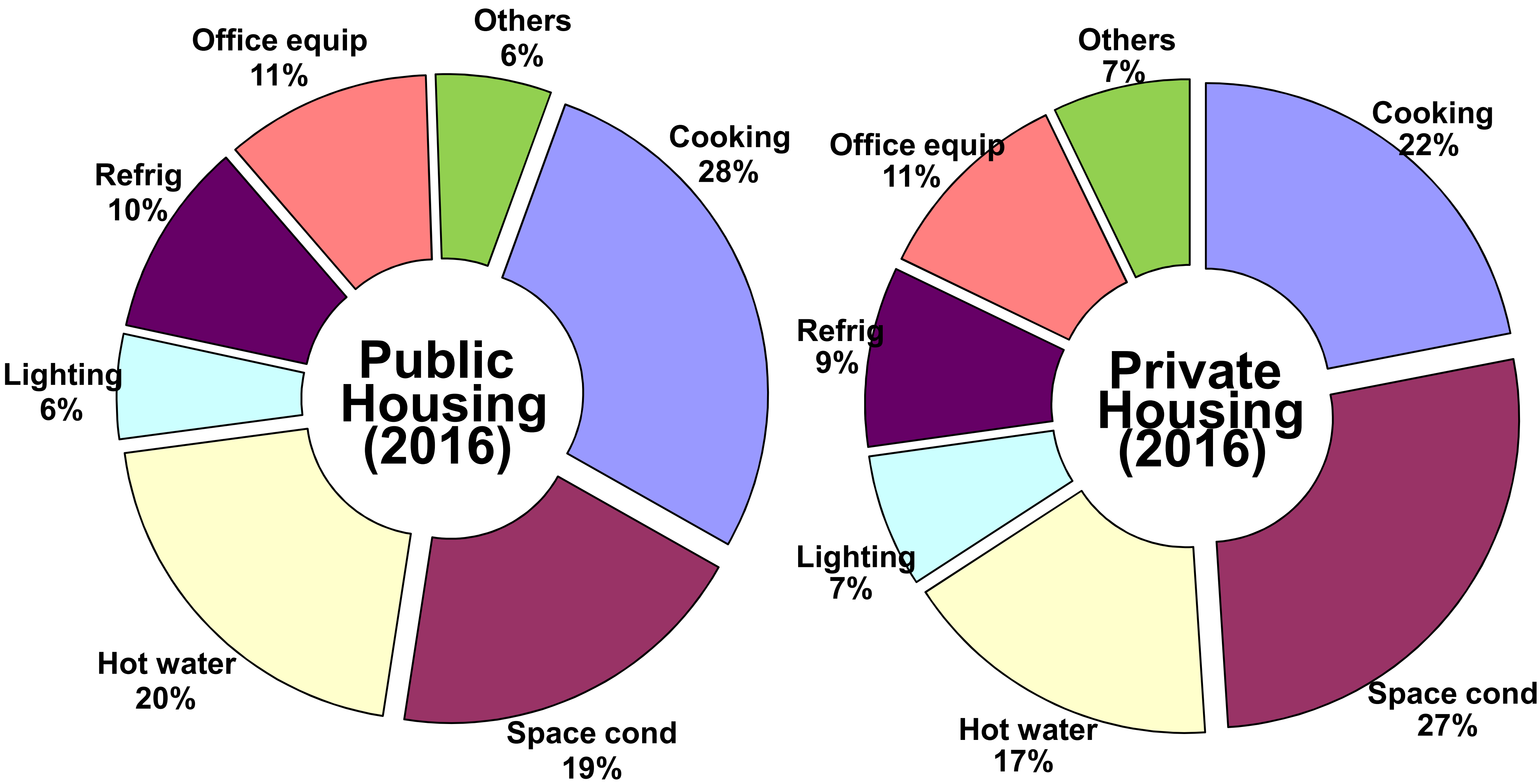


Energy consumption patterns in other commercial buildings
(Data source: Energy Efficiency Office, HK)



Energy end-use in residential sector, 2016
(Data source: Energy Efficiency Office, HK)

What are the major energy usages?



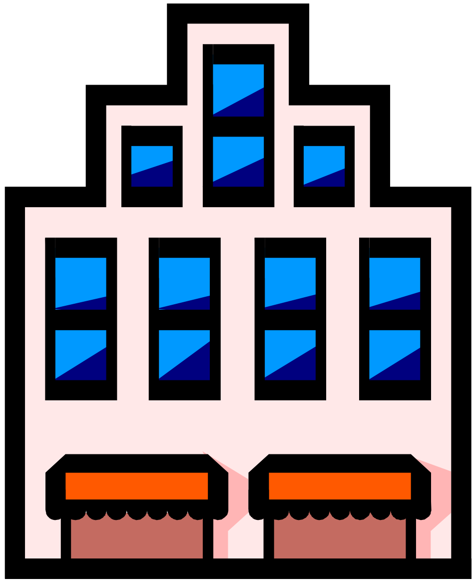
Energy consumption patterns in residential buildings
(Data source: Energy Efficiency Office, HK)

Energy Efficiency

- Key persons in building energy efficiency
  - Building Developer or Owner (Client)
  - Architect
  - Building Services Engineer
  - Building/Facility Manager
  - End-Users

Energy Efficiency

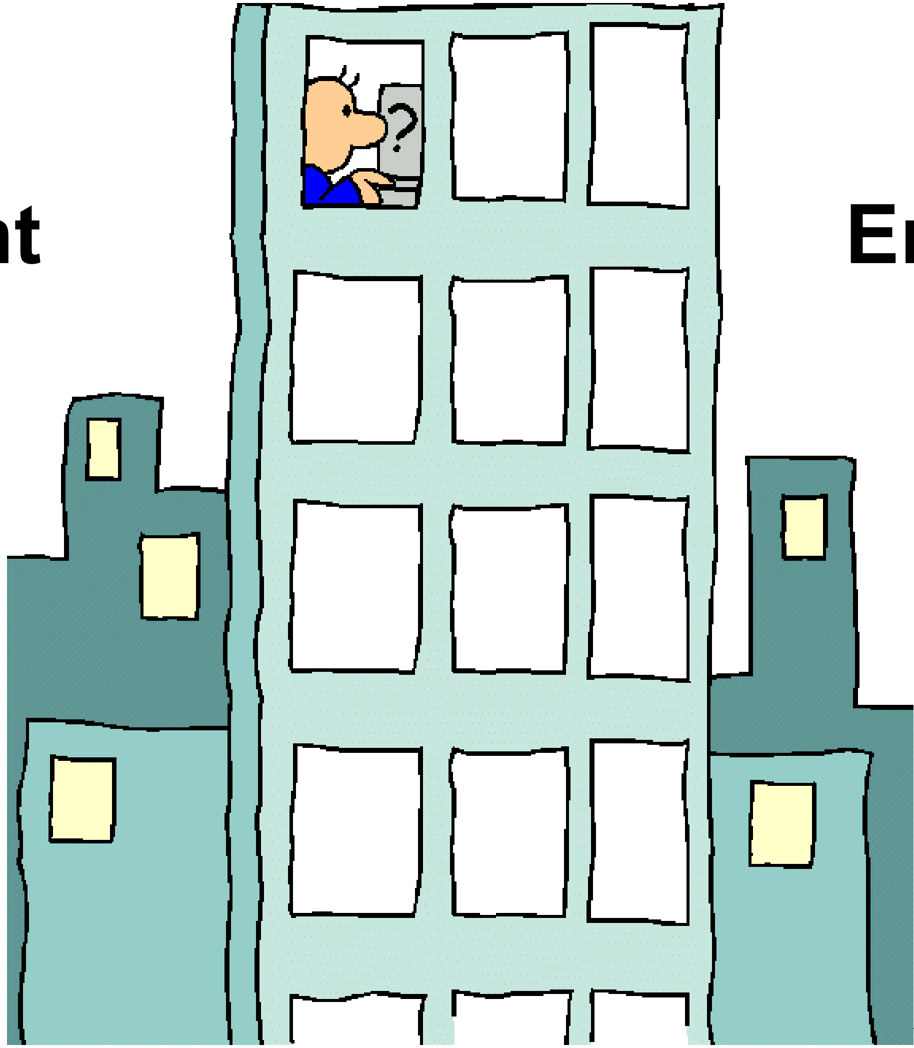
- For new buildings
  - Designing the building
    - Design strategy
    - Control strategies
    - Commissioning
- For existing buildings
  - Operating and upgrading the building
    - Building management
    - Refurbishment/renovation/retrofitting
    - Maintenance and monitoring



Design of the built environment

Shelter

Outdoor Environment



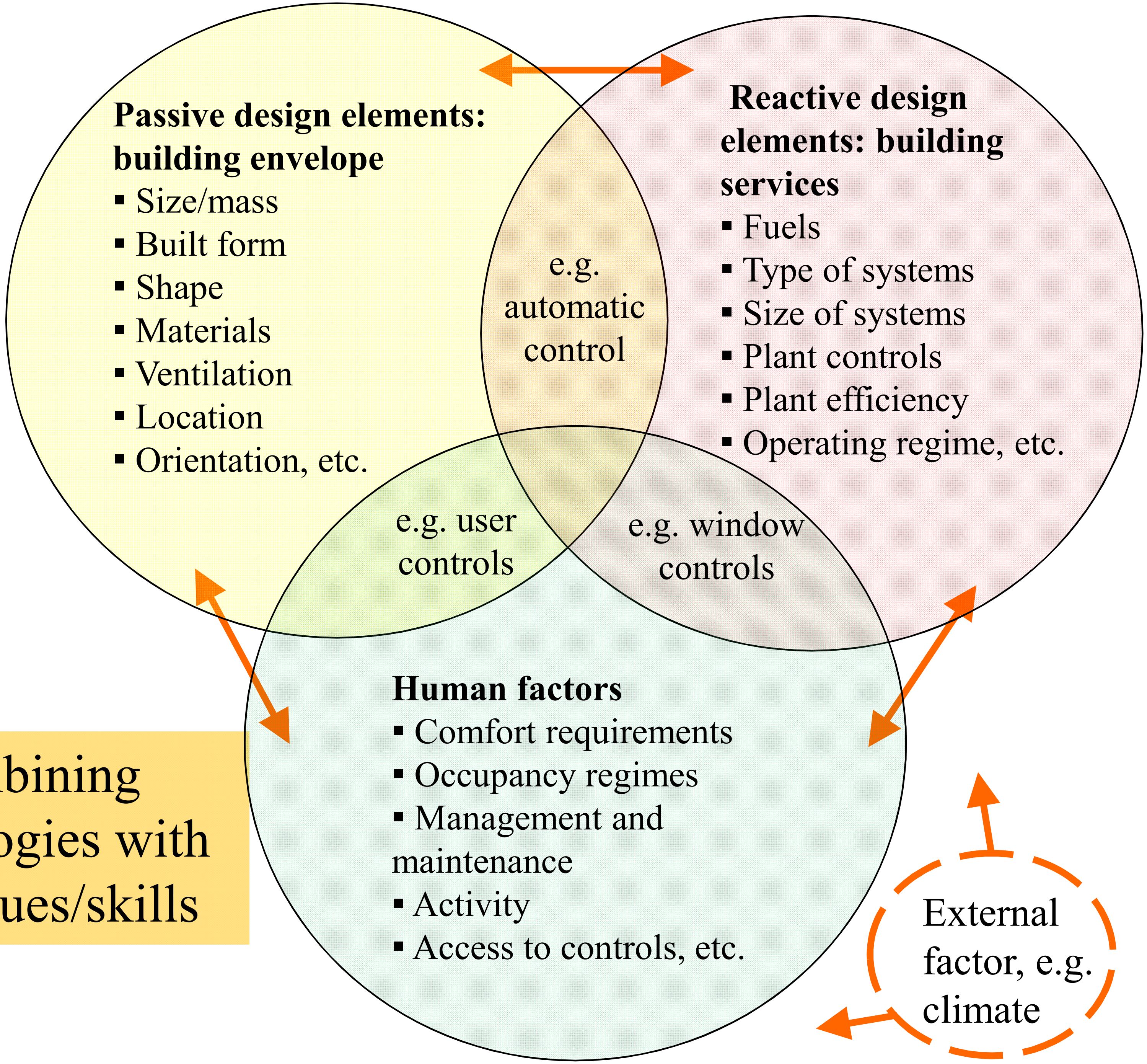
Human Environment

Energy supply to the building

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

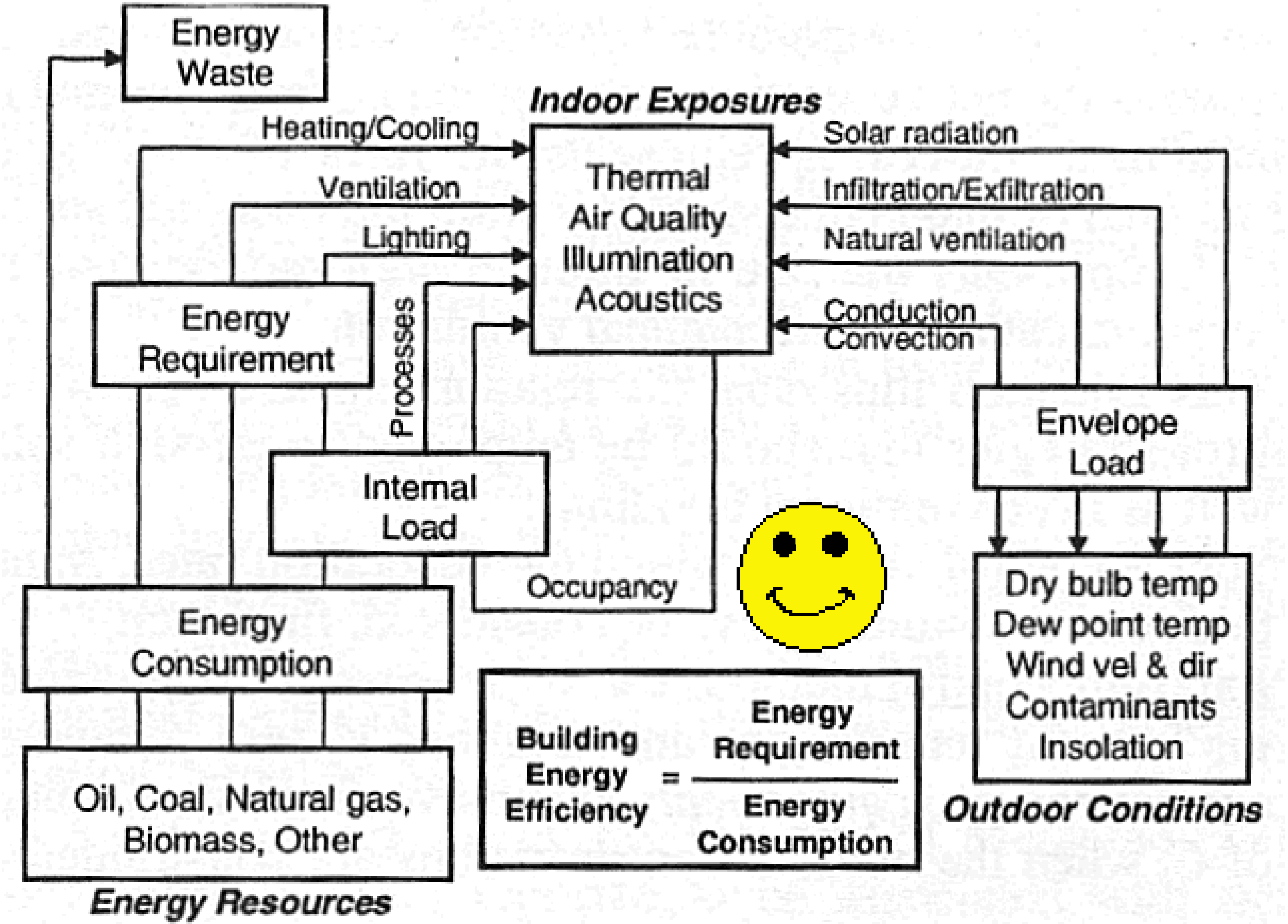
Do you know how to study energy efficient buildings?

Combining technologies with techniques/skills



Key factors influencing energy consumption

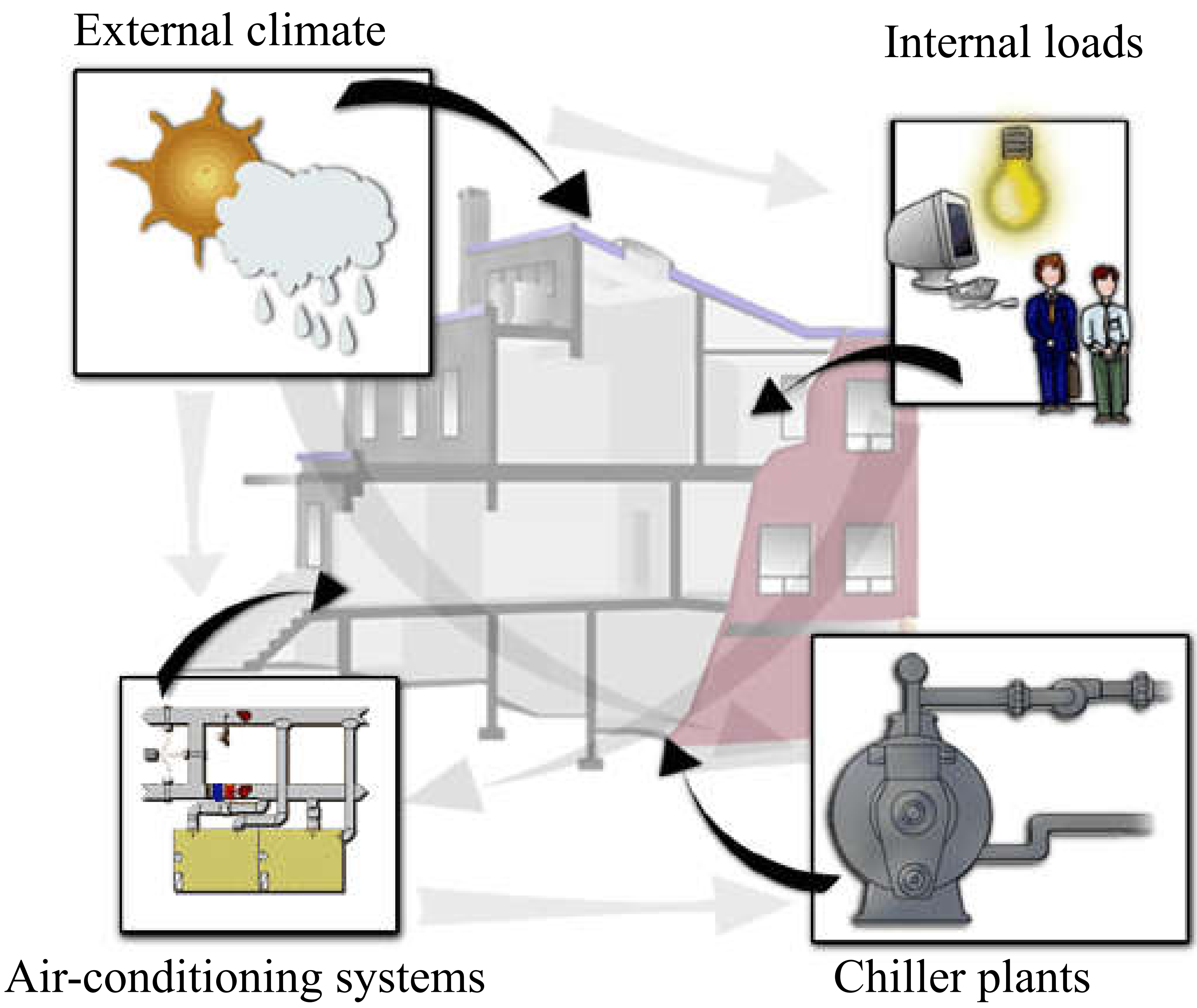
(Adapted from Energy Efficiency in Buildings: CIBSE Guide F)



Energy flow and concept in buildings

Energy Efficiency

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

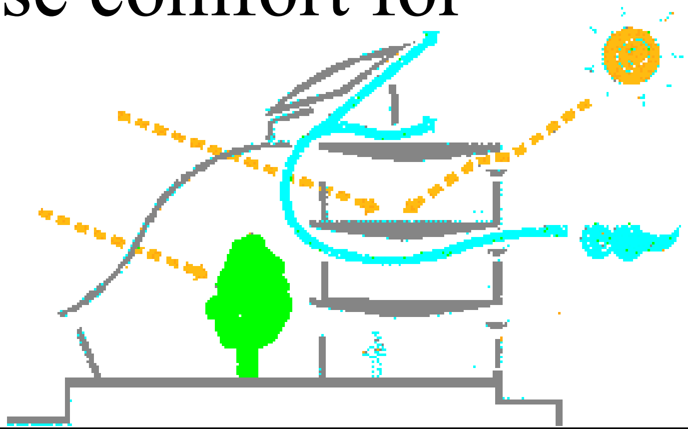

External climate
Internal loads
Air-conditioning systems
Chiller plants

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

Energy Efficiency

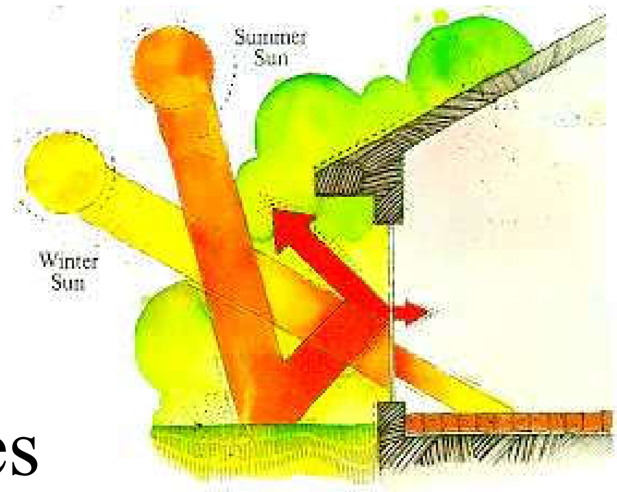
- Passive design (被動式設計)
  - Design the building and the spaces within it to benefit from *natural light, ventilation* and even temperatures
  - Ensure the fabric of the building and the spaces within it *respond* effectively to *local climate and site conditions* in order to maximise comfort for the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



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

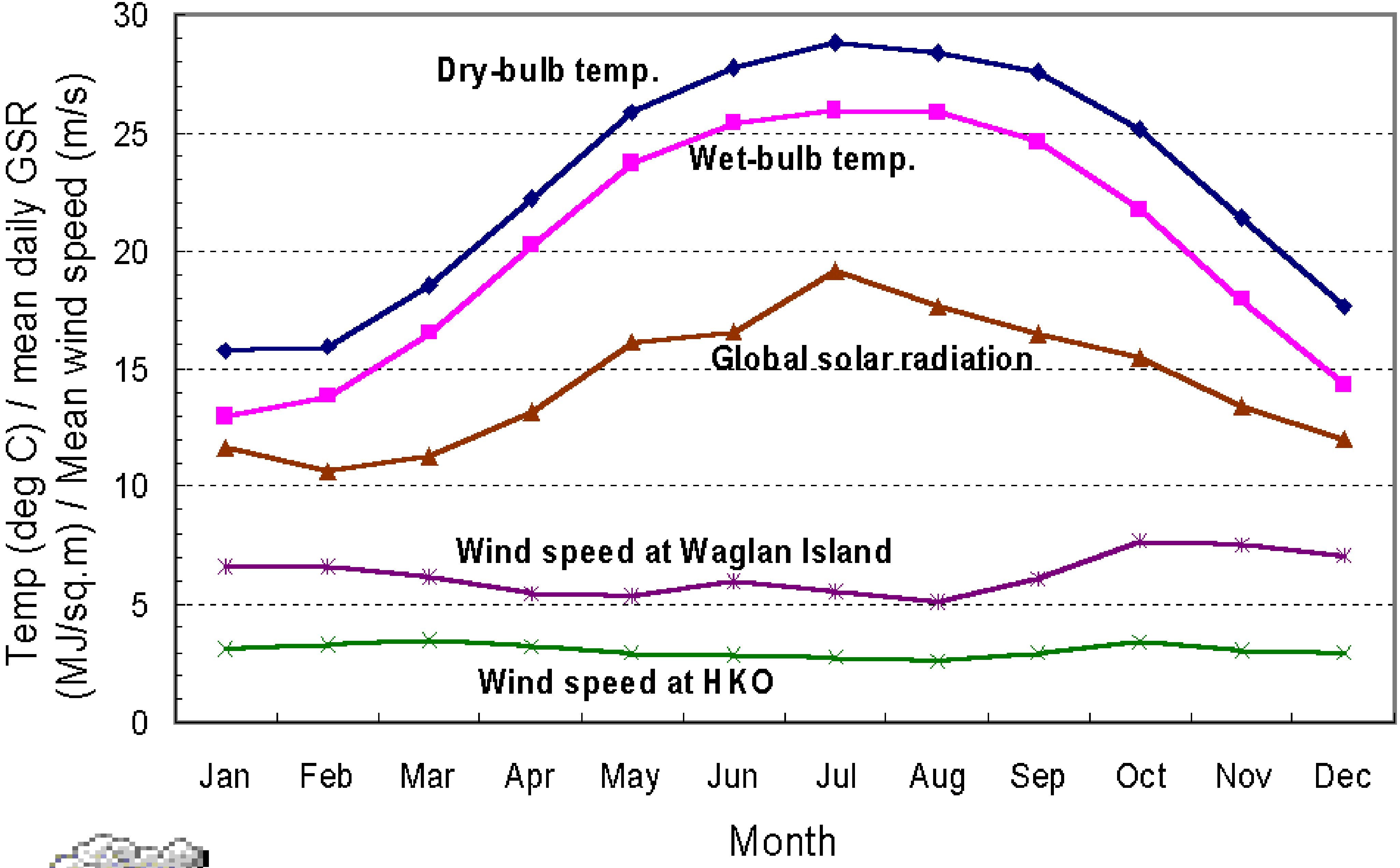
Energy Efficiency

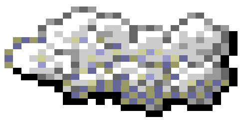
- Key factors of passive design:
  - Climate and site analysis
  - Solar design and shading control
  - Correct orientation and use of windows
  - Use of thermal mass and insulation
  - Provision for ventilation (natural)



- Further reading:
  - Passive Cooling in Tropical Climates
    - http://www.btsquarepeg.com/sustainable/energy/passive-cooling-in-tropical-climates/

Major climatic elements of Hong Kong





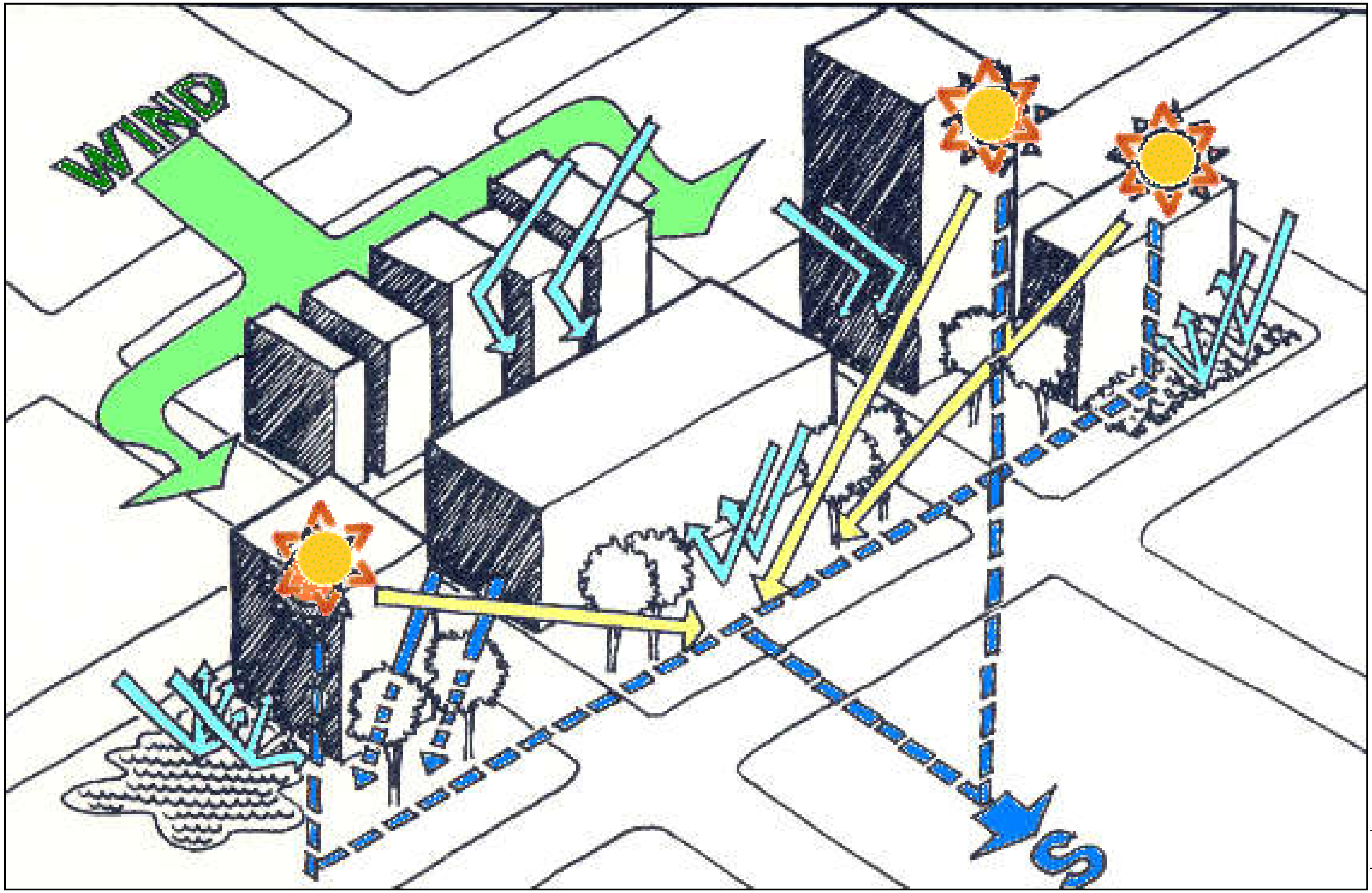
Building designer is like a “Feng Shui” master.

風

Wind

光

Light



水

Water

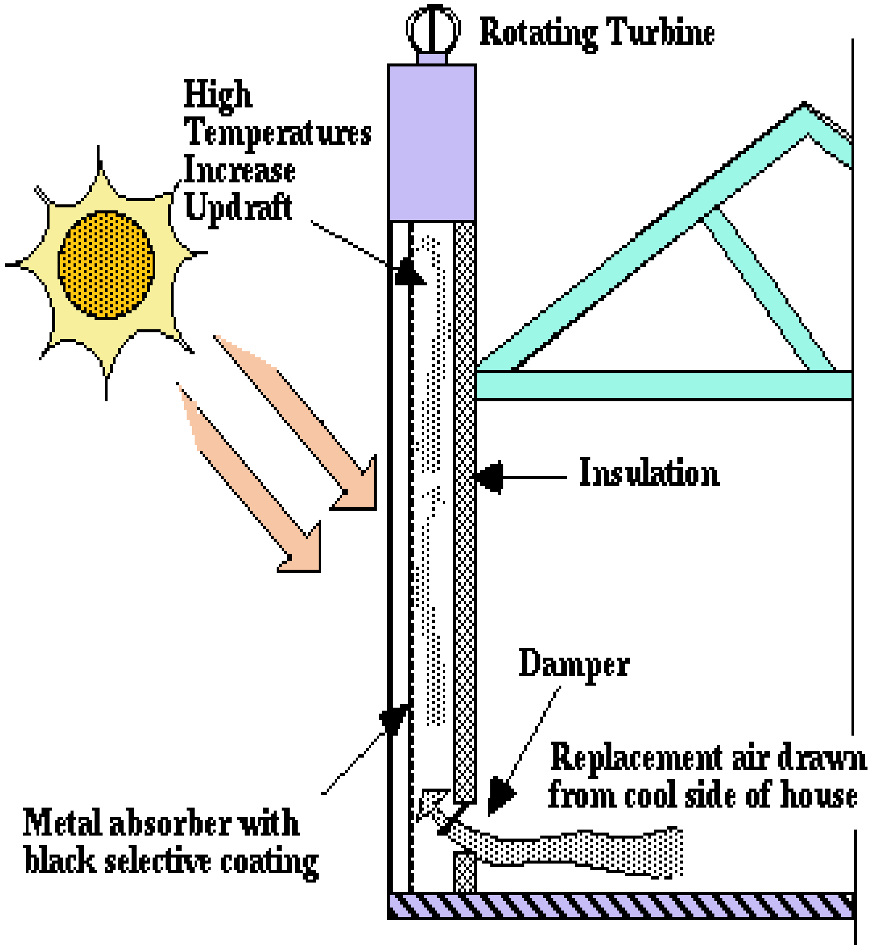
物

Matter

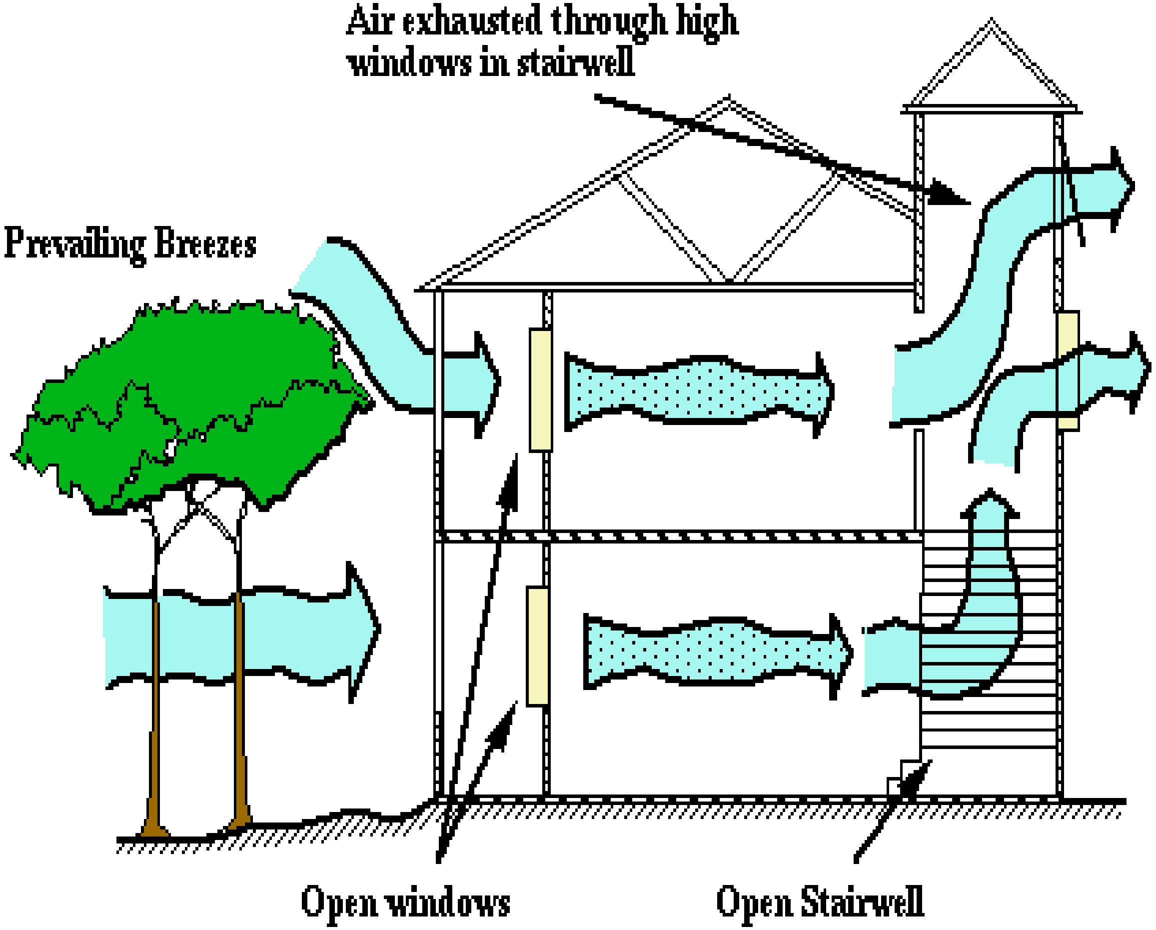
Major site factors

Examples of passive cooling designs

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



Thermal chimney

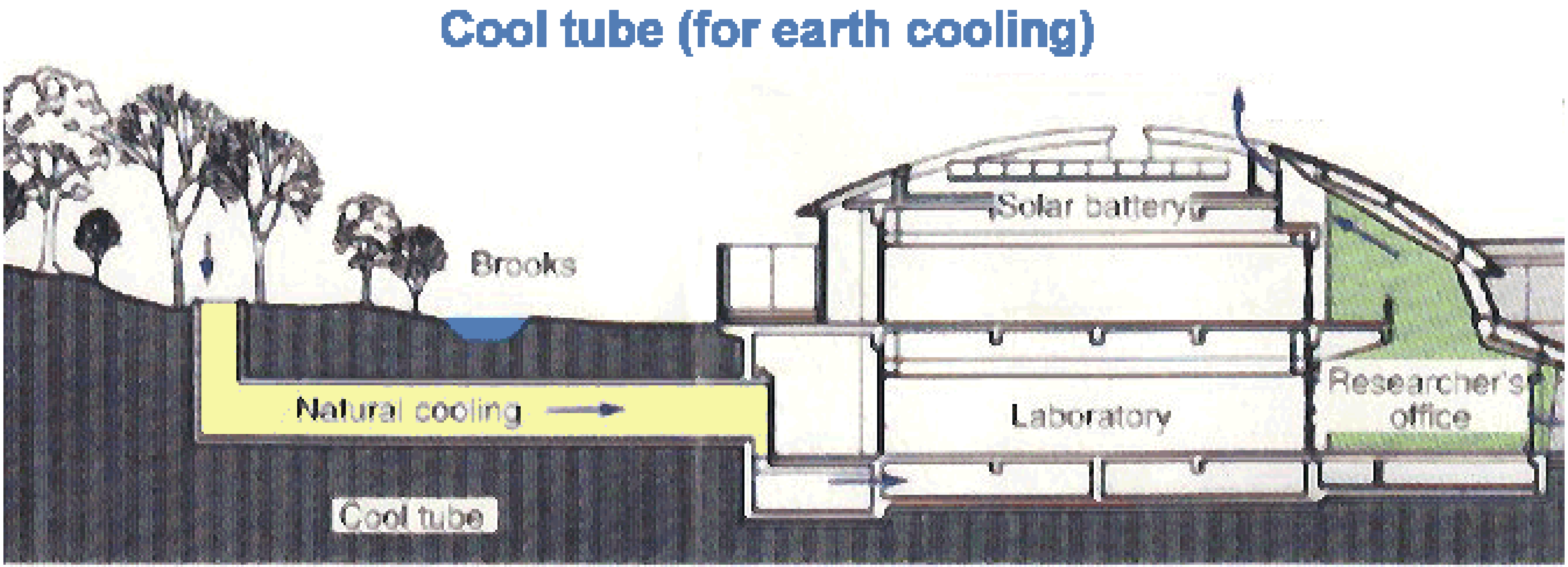


Natural ventilation

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

Examples of passive cooling designs

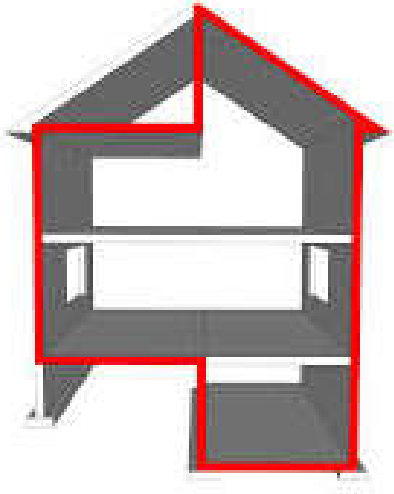
(outdoor fresh air cooled by the earth before entering the building)



Earth tube cooling (Japan)

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 (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)



* Face House, Kyoto, Japan

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

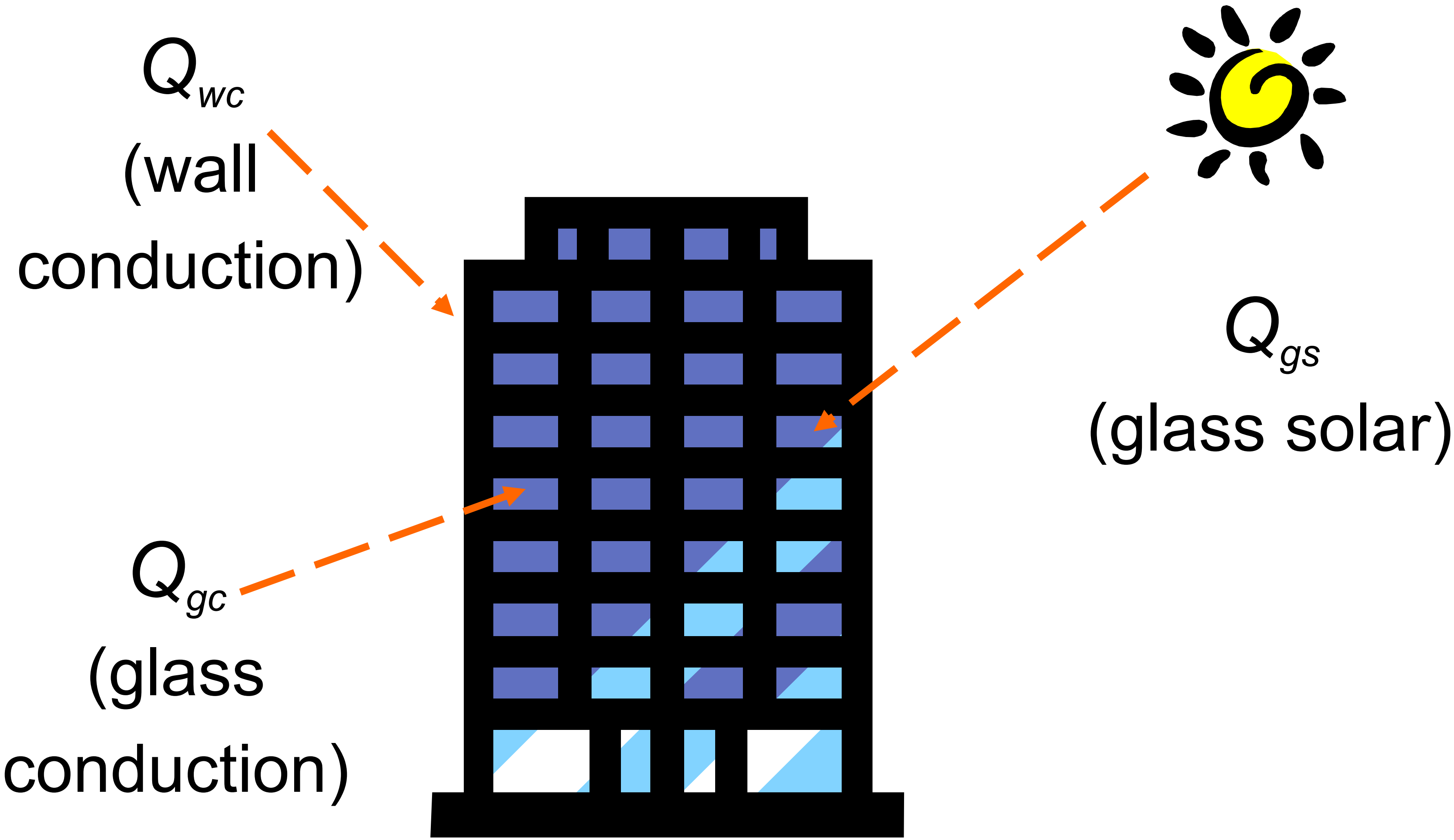
Main criteria:

- wall area
- window area
- thermal properties
- orientations
- thermal mass
- shading device

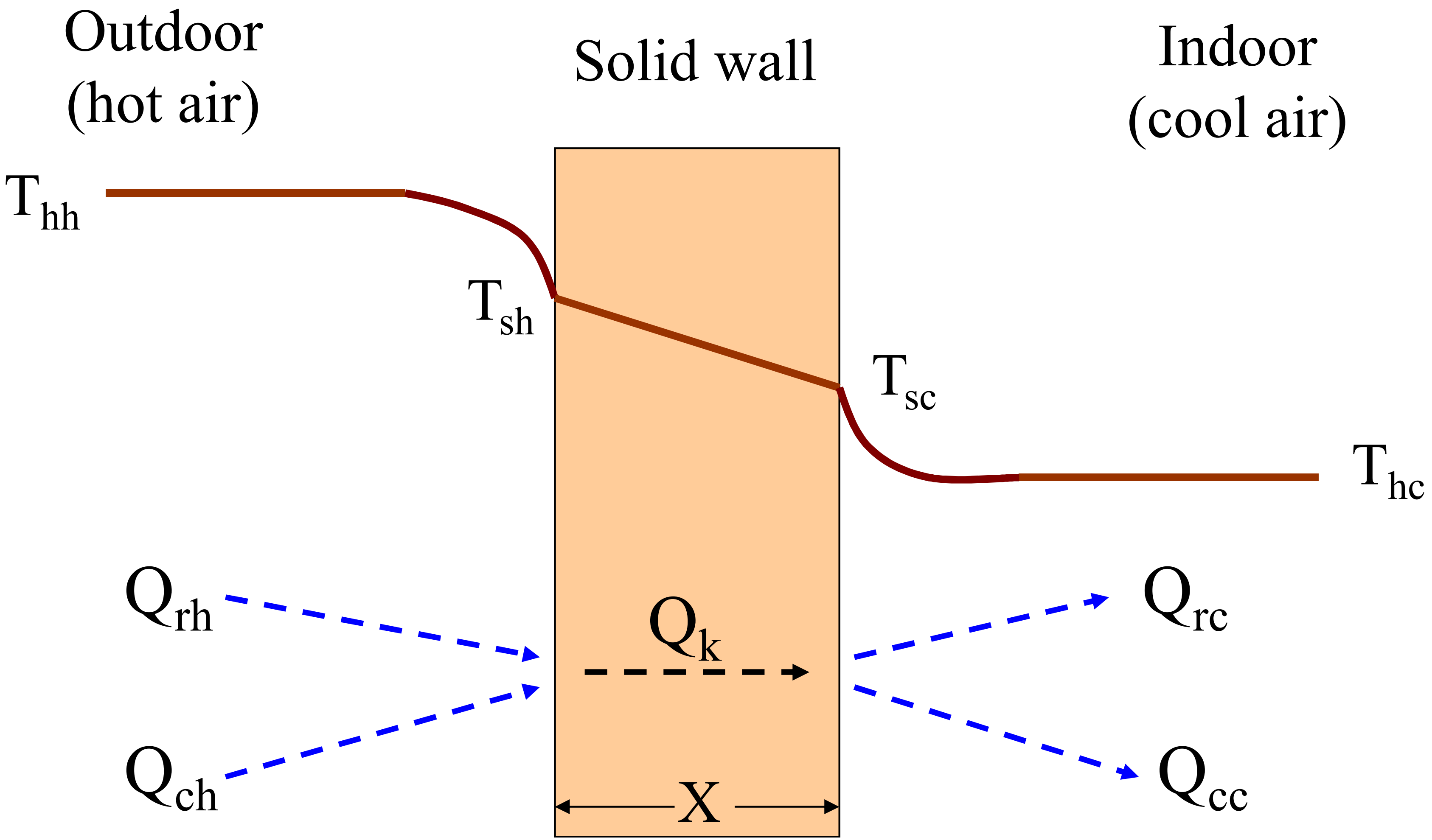
Heat transmission through building envelope

(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

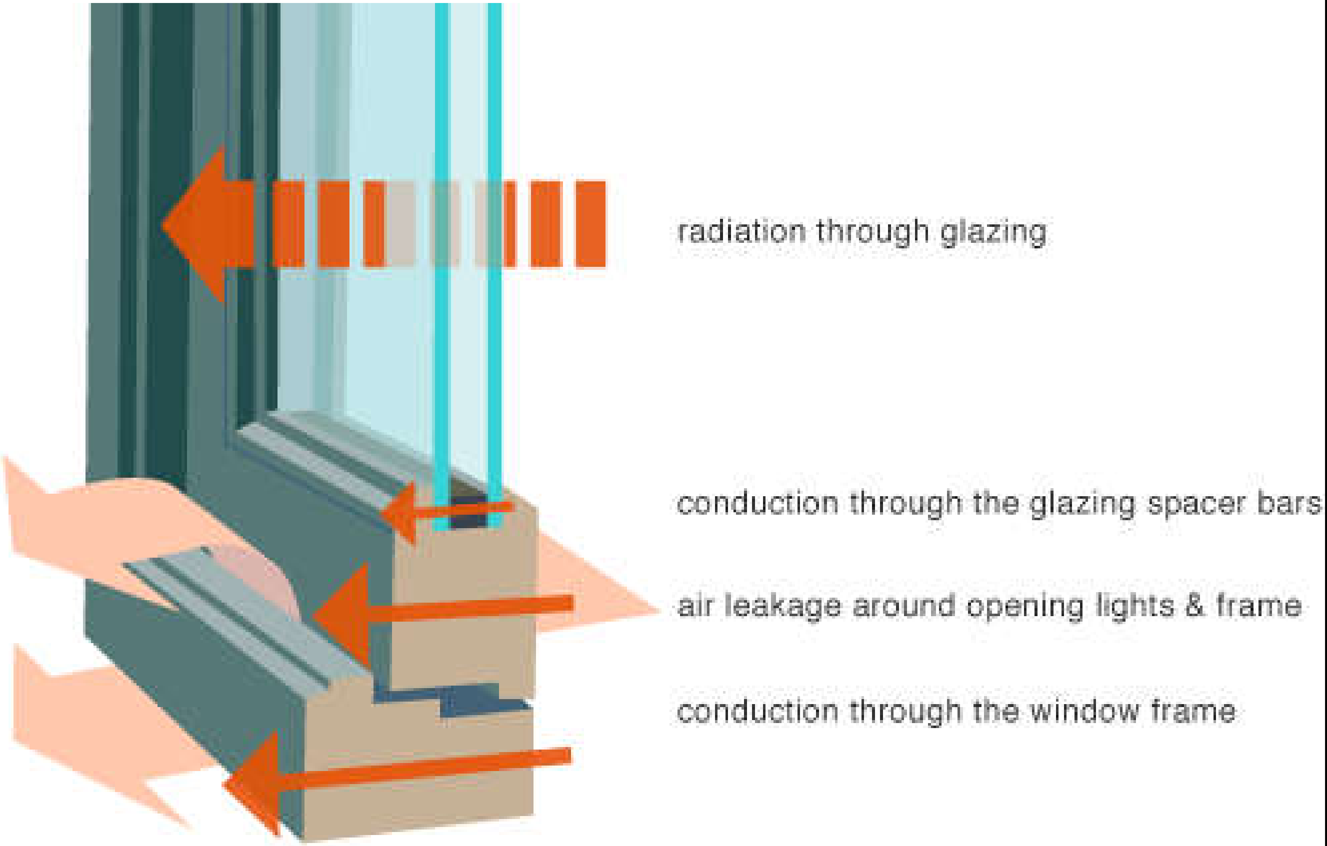
Energy Efficiency

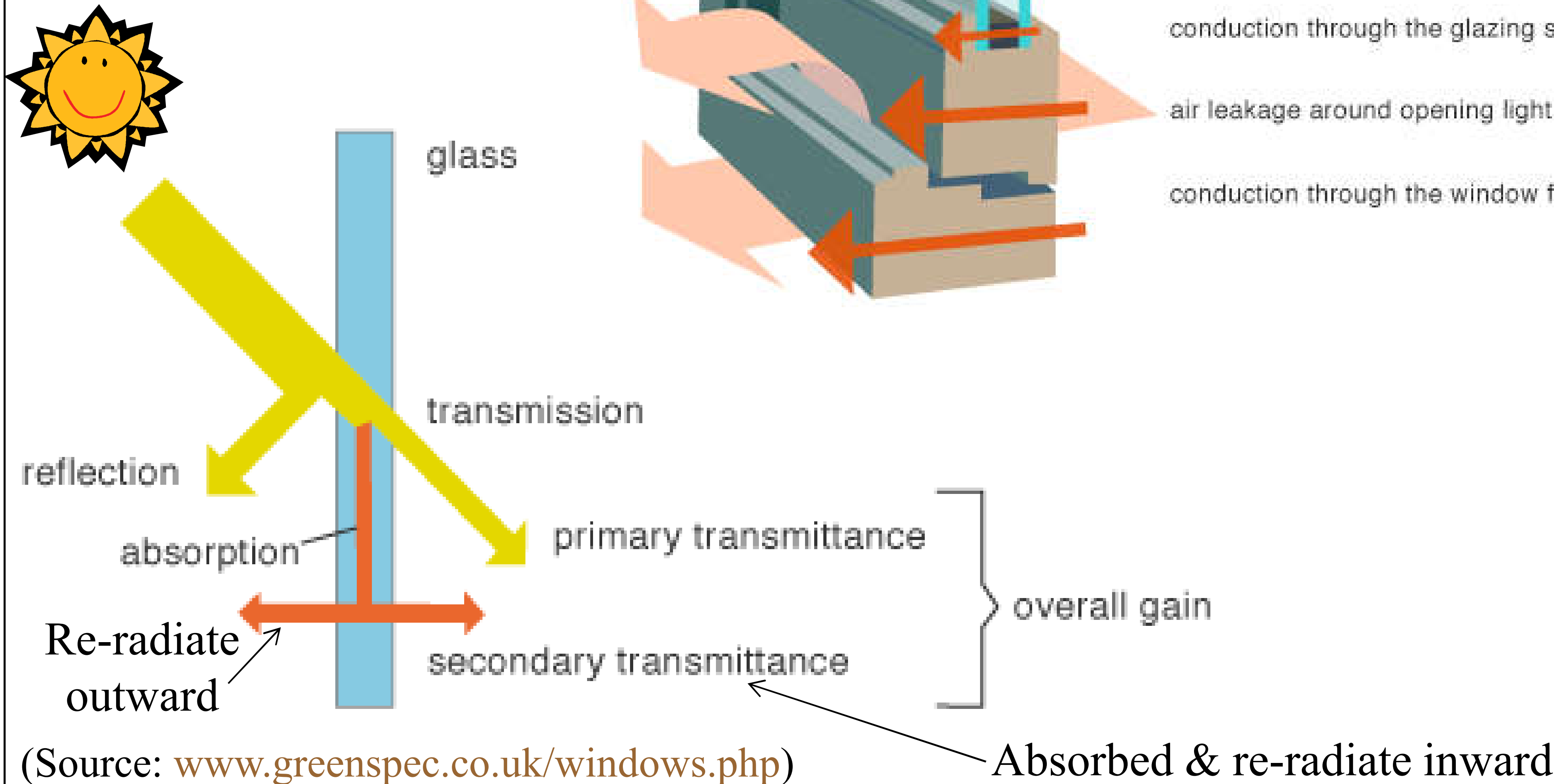
- Major factors determining envelope heat flow:
  - Temperature differential, ΔT
  - Area of exposed building surfaces, A
  - Heat transmission properties, like U-value
  - Thermal storage capacity
  - Window-to-wall ratio (WWR)

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

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

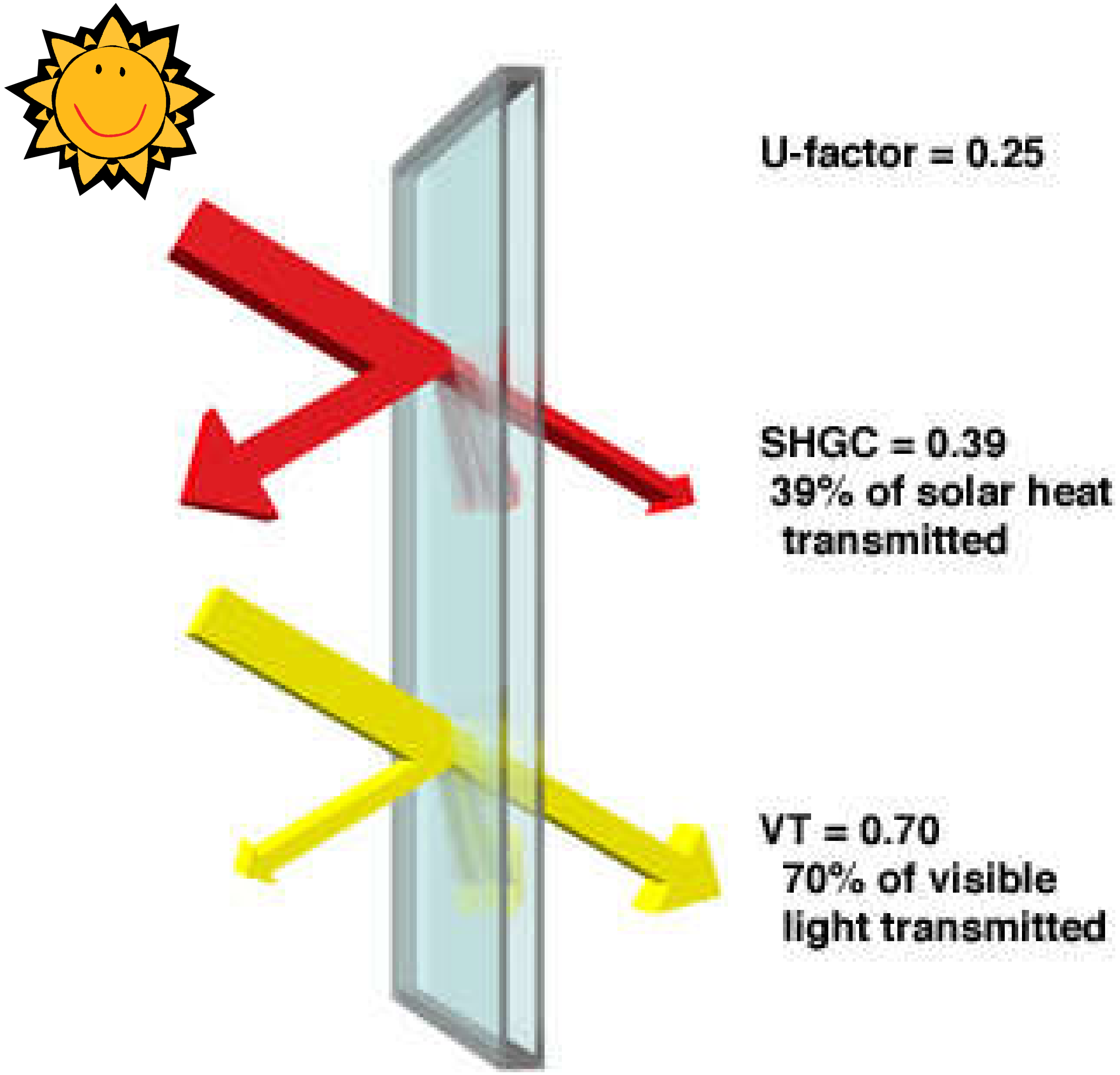
Solar heat gain and heat loss through window glass





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

Understanding window performance



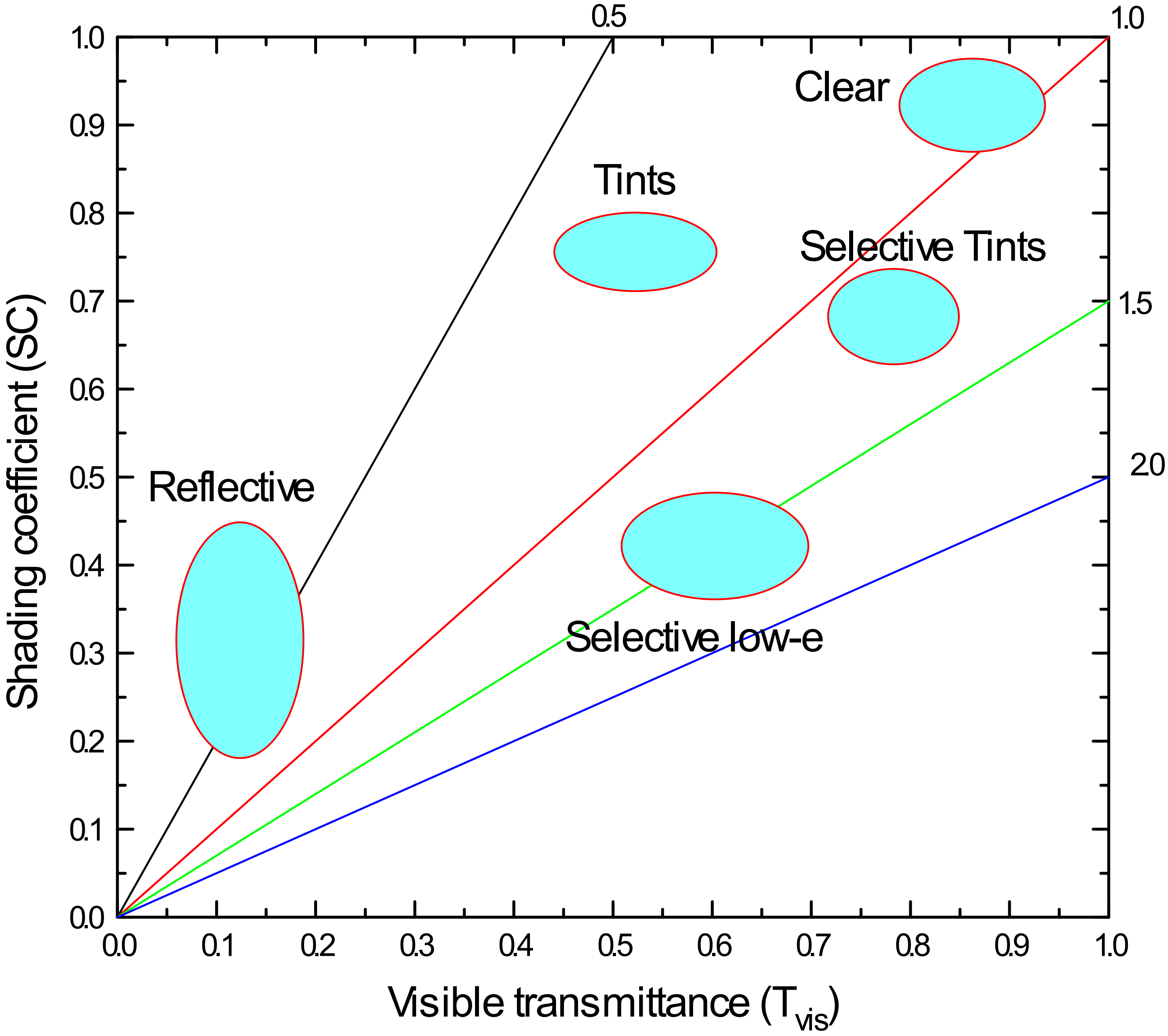
U-factor (or U-value) = overall thermal transmittance ($W.m^{-2}.K^{-1}$)

SHGC = solar heat gain coefficient

VT = visible transmittance

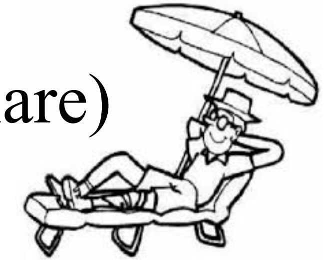
$$Shading\ Coefficient\ (SC) = \frac{Solar\ heat\ gain\ of\ the\ window\ glazing}{Solar\ heat\ gain\ of\ unshaded\ 3\ mm\ clear\ float\ glass}$$

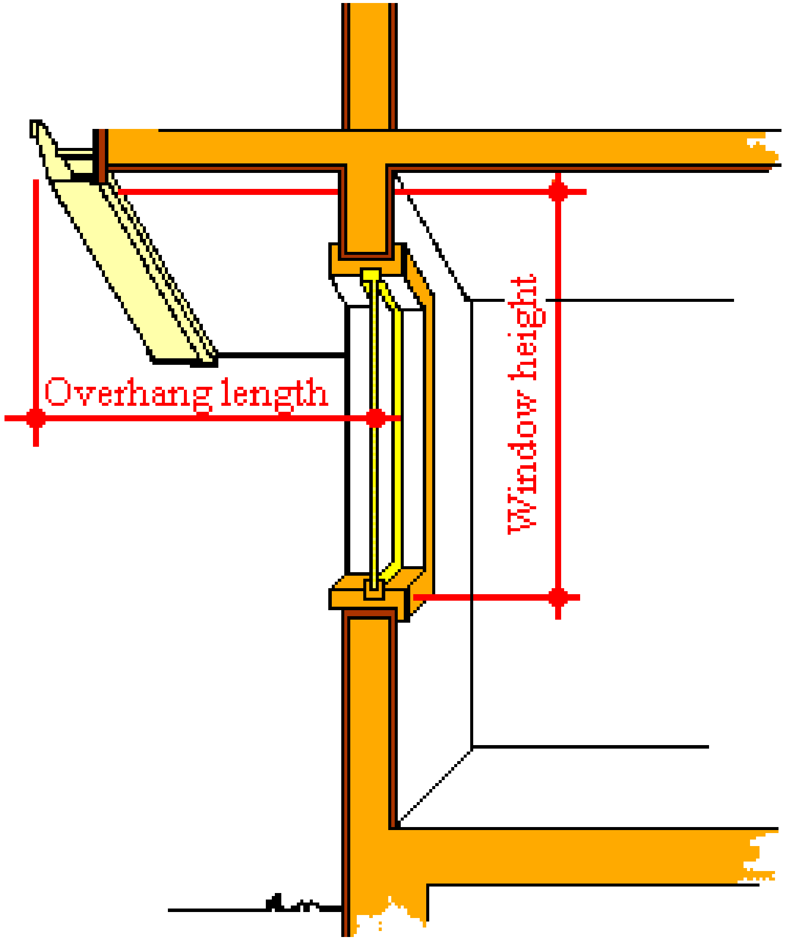
Properties and selection of window glasses



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

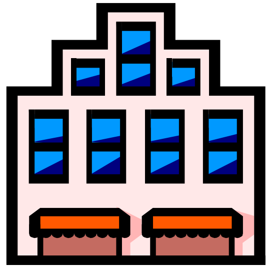
Roller shades

Energy Efficiency

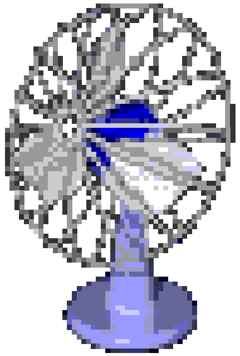
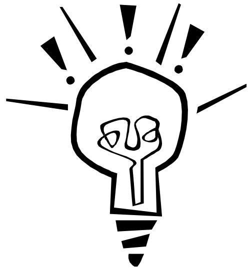
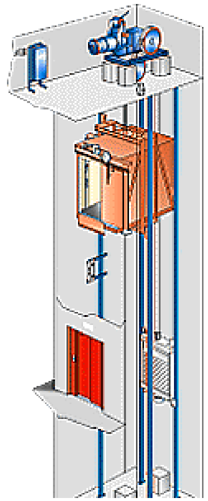
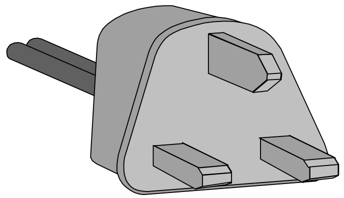
- Architects and Engineers work together to
  - Evaluate envelope performance at early stage
  - Select appropriate window design and materials
  - Design thermal insulation and building fabric

- Complicated issues with building envelope:
  - Dynamic behaviour of climate and building
  - Interaction of light and heat
  - Use of daylighting and solar energy systems

Building Services Systems



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


Energy efficiency labels in HK

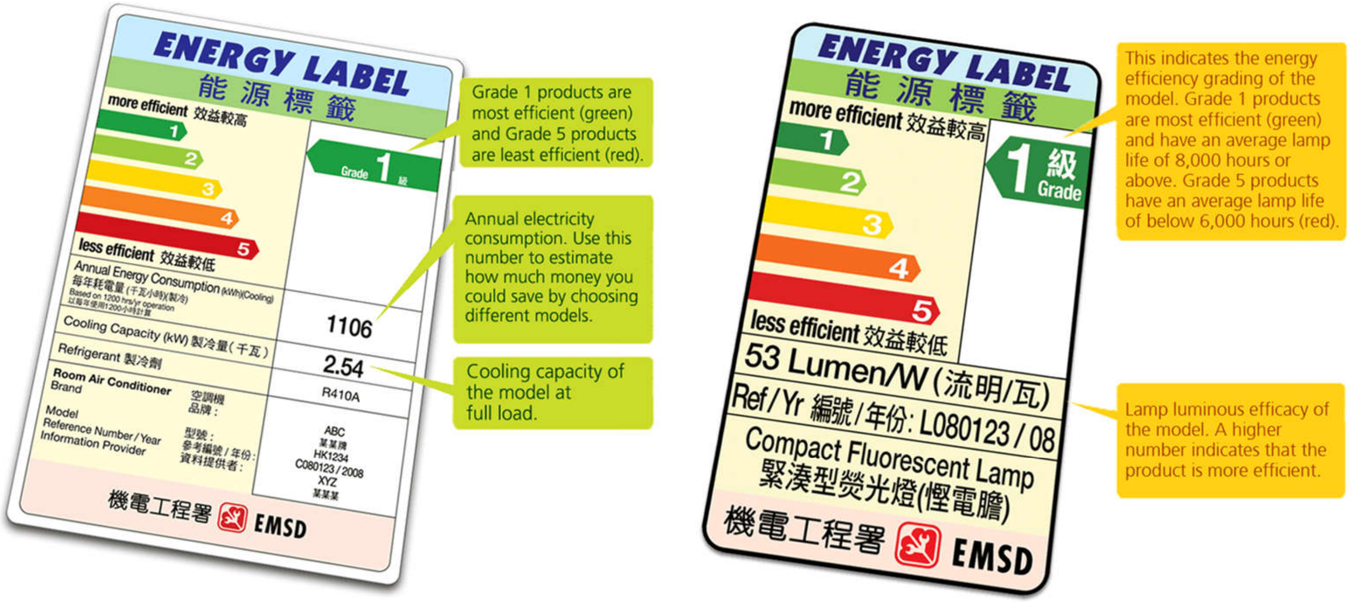


Figure 4.8 Examples of mandatory energy efficiency labels in Hong Kong

Figure 4.9 Examples of voluntary energy efficiency labels in Hong Kong

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

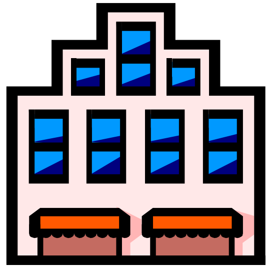
Comparing different grades of energy efficiency labels*

節省能源的百分比 Percentage of Energy Saving

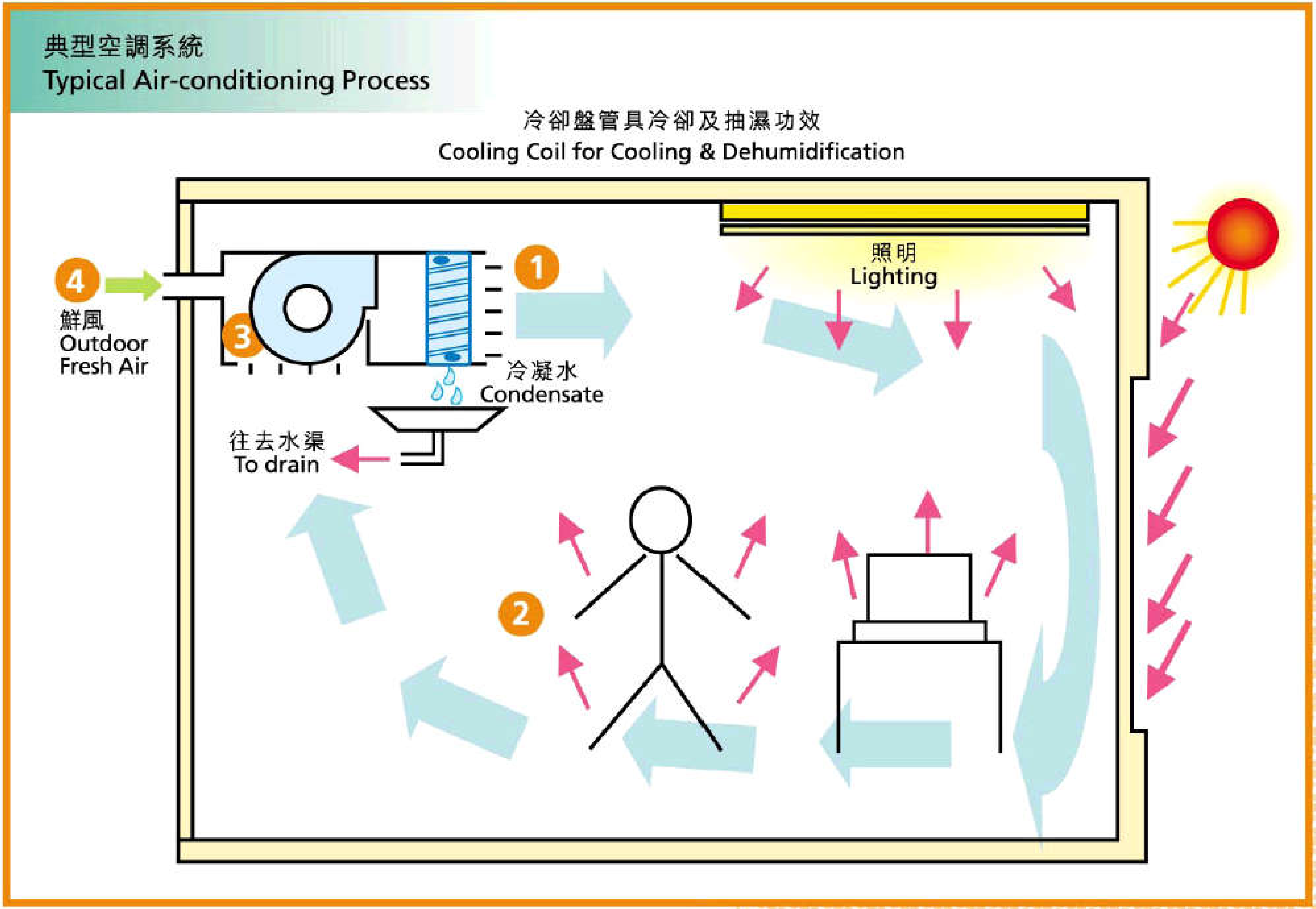
	空調機 Room Air Conditioners	冷凍器具 Refrigerating Appliances	慳電膽 Compact Fluorescent Lamps	洗衣機 Washing Machines	抽濕機 Dehumidifiers
第1級比第3級 Grade 1 vs Grade 3	15%	35%	14%	25%	24%
第1級比第5級 Grade 1 vs Grade 5	29%	49%	18%	40%	42%

(*See also https://www.emsd.gov.hk/energylabel/)

Building Services Systems

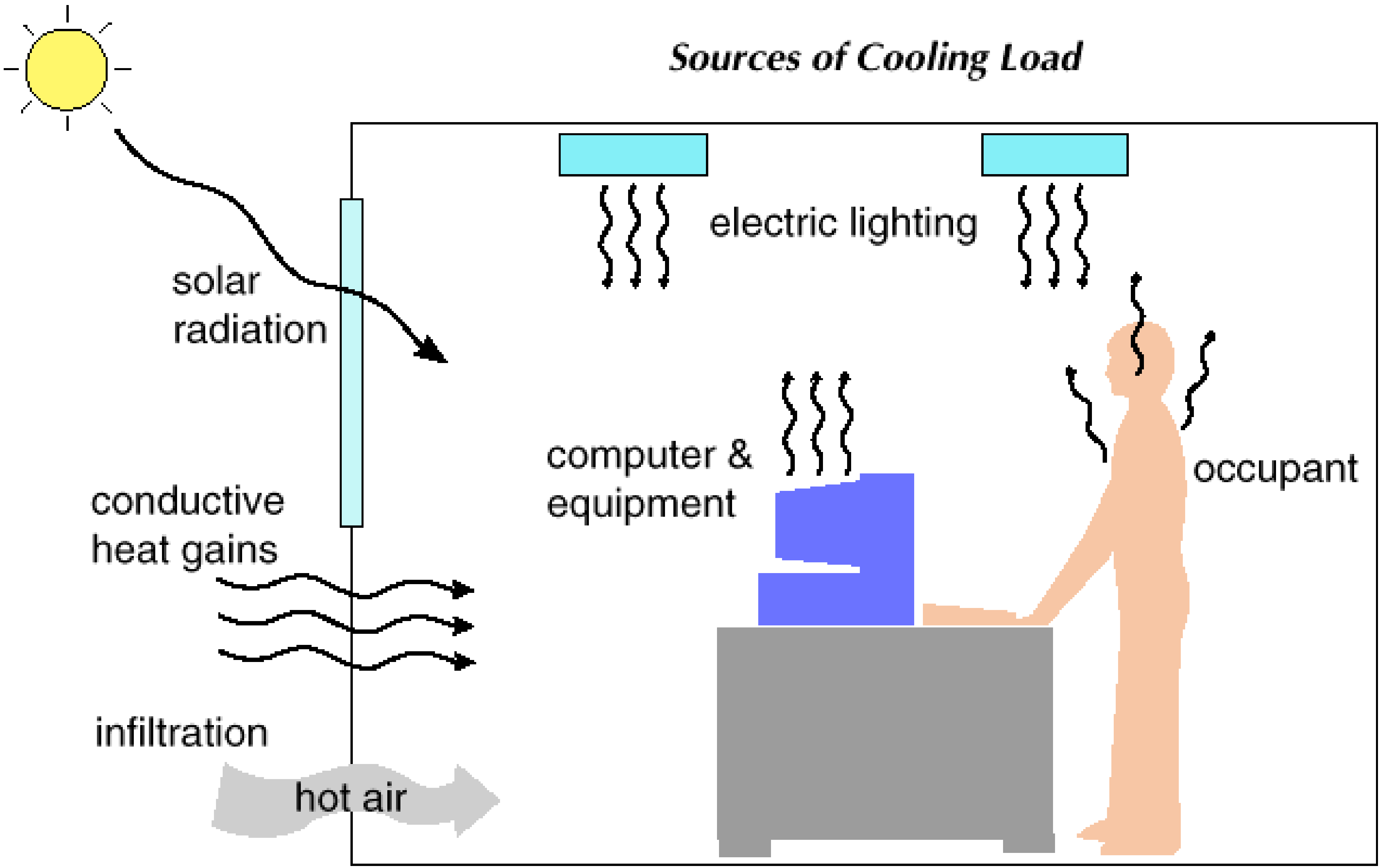


- Heating, ventilating & air-conditioning (HVAC) systems
  - Usually the most important energy users
  - Provide for occupant comfort, health and safety
  - HVAC design is affected by architectural features and occupant needs
- In Hong Kong, heating load is small and main focus is on air-conditioning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



(Source: EnergyWitts newsletter, EMSD)

Heat flow and sources of cooling load



Building Services Systems

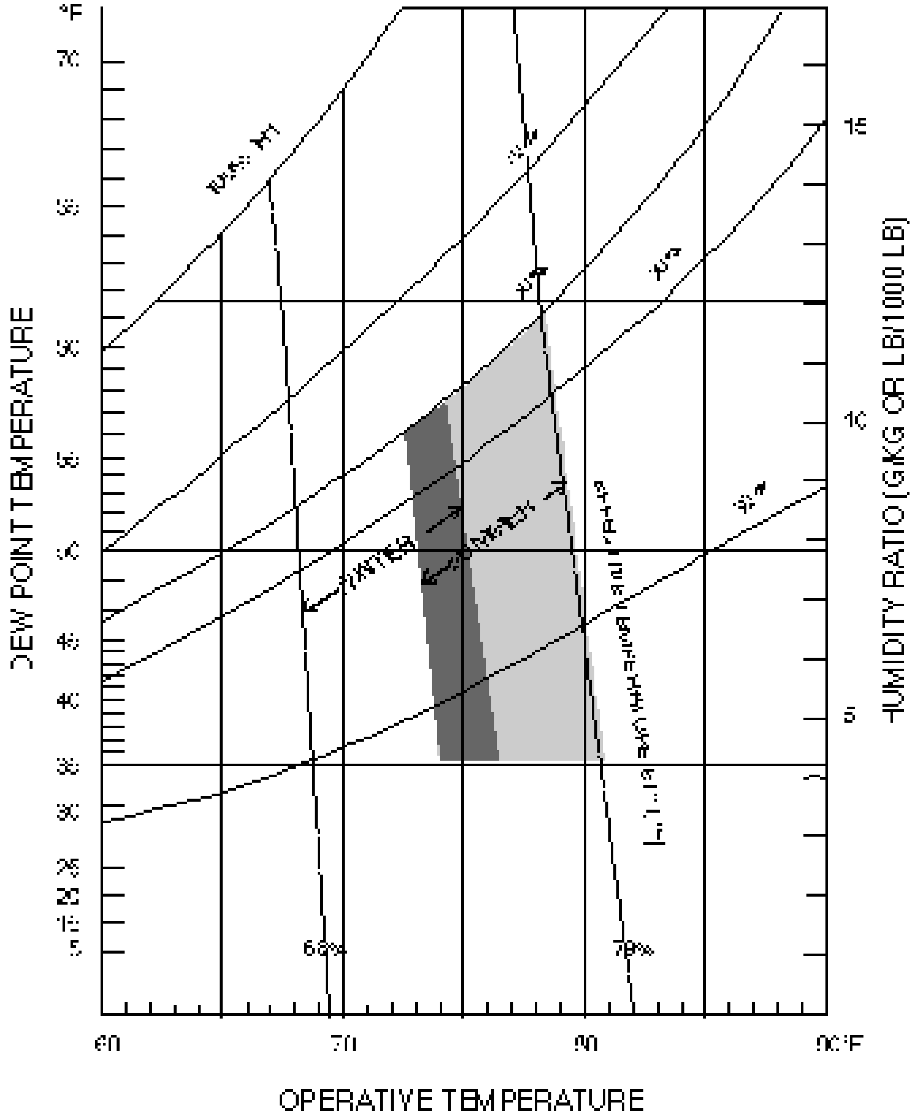
- Strategies for energy efficiency of HVAC*
  - 1. Reduce heat load in the air-conditioned spaces
  - 2. Promote natural cooling or ceiling fans, prior to using mechanical cooling
  - 3. Adopt “relaxed dress code” and flexible work schedule, wherever possible
  - 4. Ensure good house-keeping and user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

(*See also High-Performance HVAC, http://www.wbdg.org/resources/hvac.php)

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

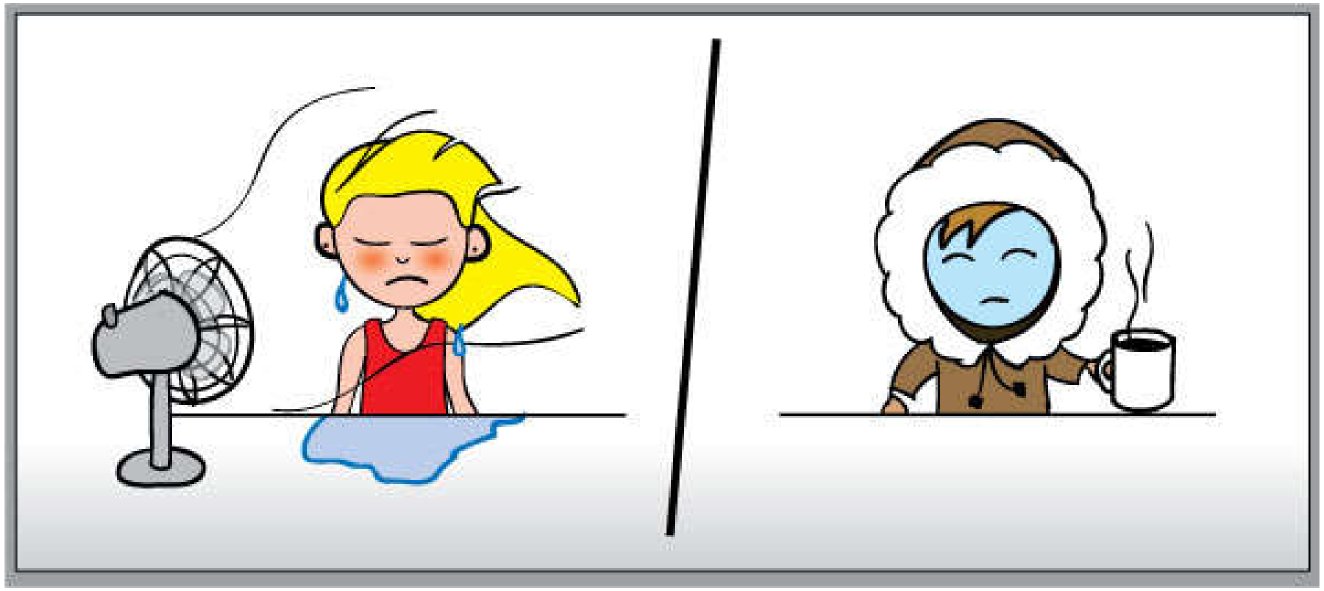
(Source: The Wall Street Journal, http://online.wsj.com)

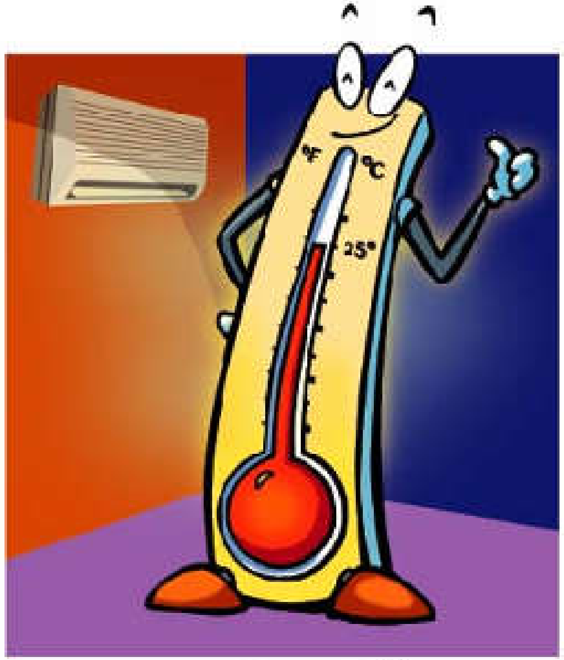
Thermal comfort criteria and design



ASHRAE comfort envelope

Thermal comfort &
design conditions

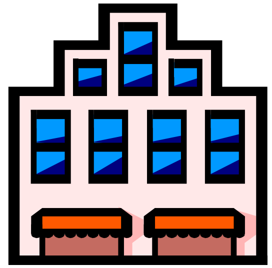




Just nice at 25°C
Electricity Efficiency Centre

Cleaner filter filters better.
Electricity Efficency Centre

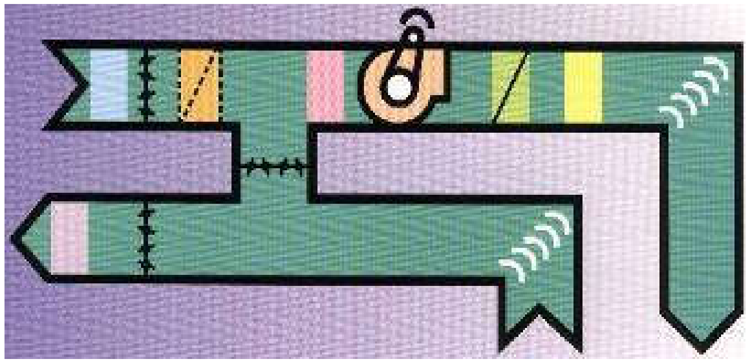
Building Services Systems



- 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

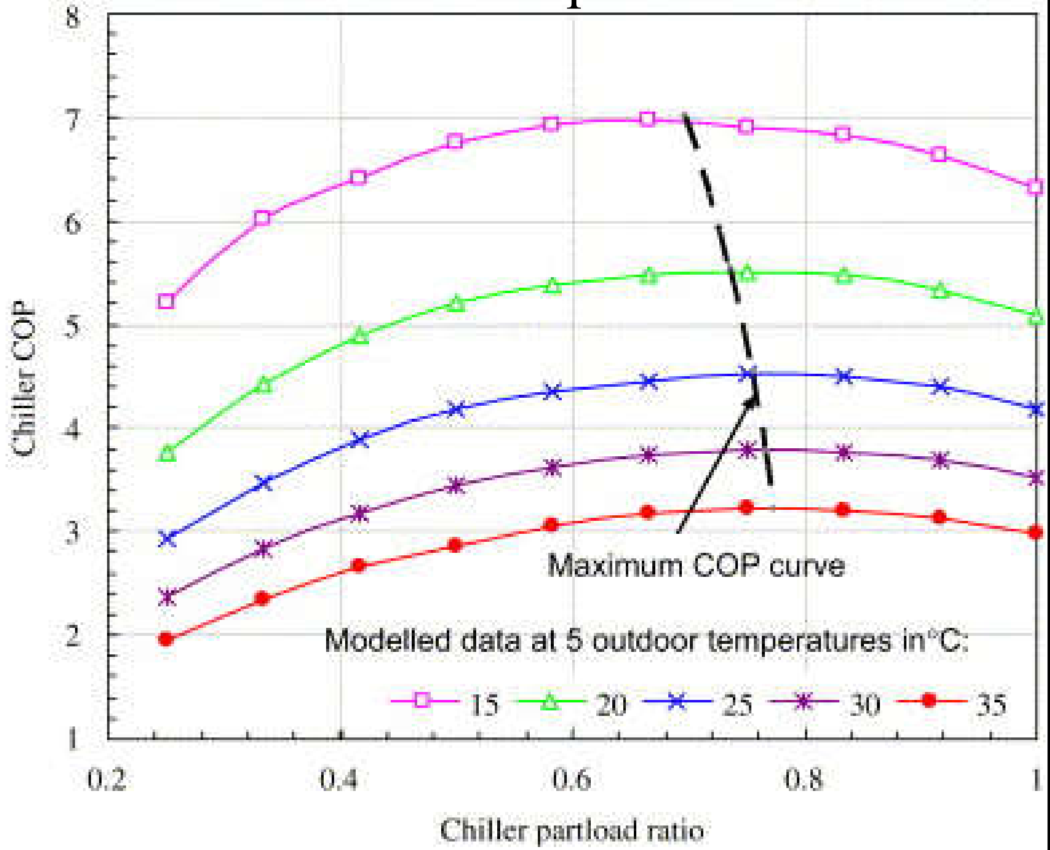
Partload efficiency of HVAC equipment and plant

Strategy: optimize equipment efficiency & part-load performance



HVAC system and plant

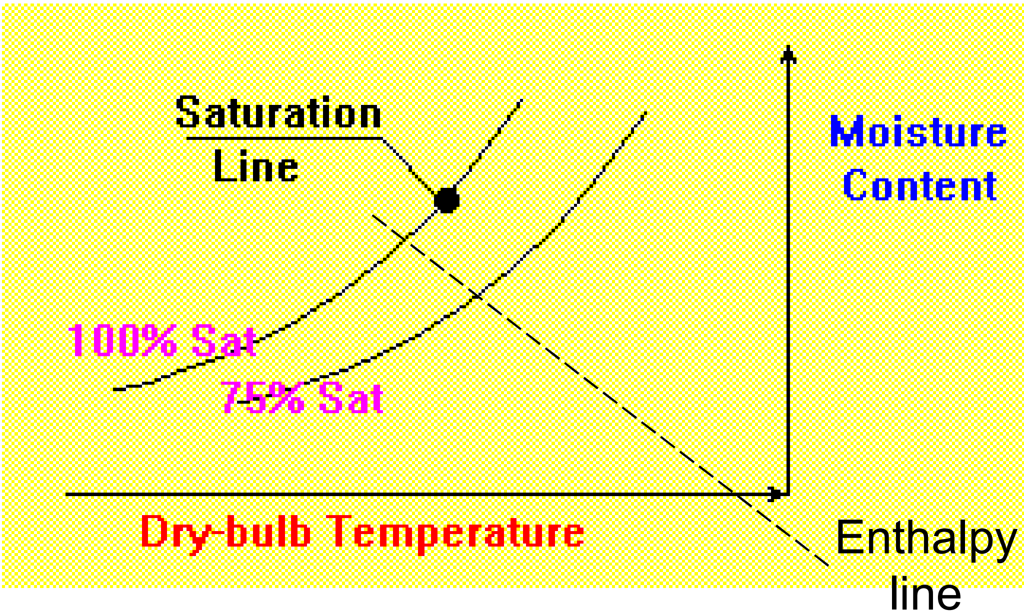
Highest efficiency at about 70%-90% partload ratio



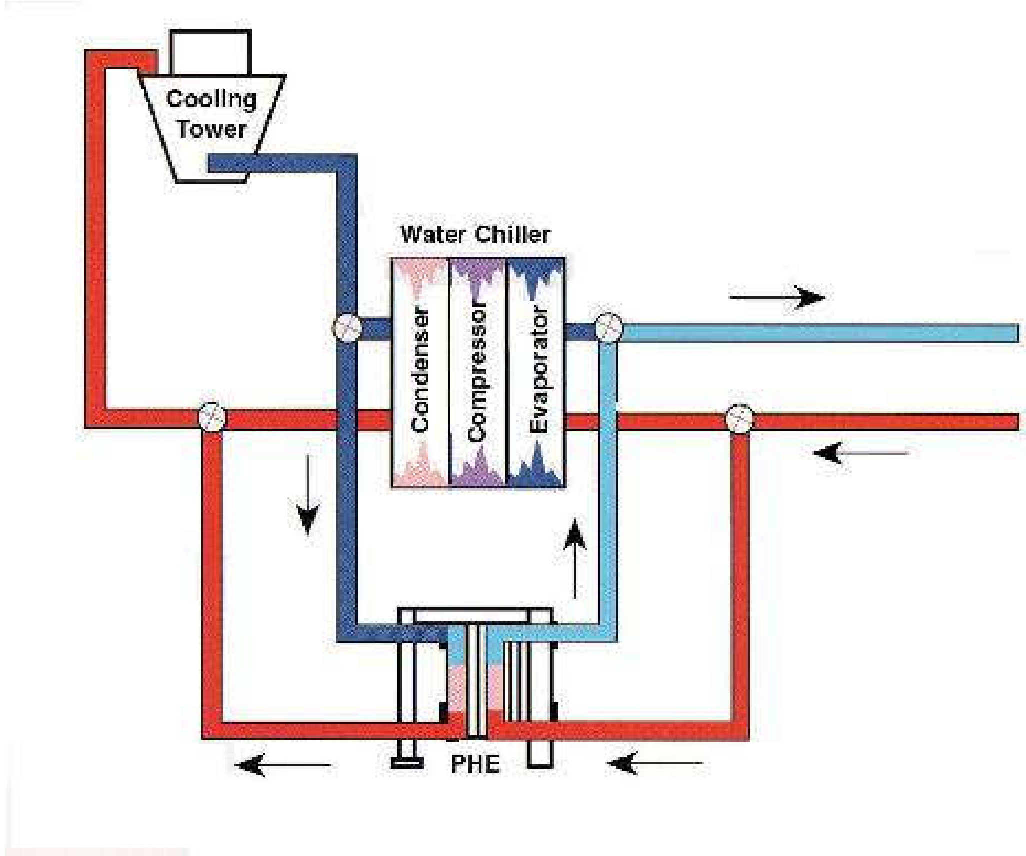
Chiller partload ratio

‘Free’ cooling methods in HVAC systems*

Strategy: use of free cooling



(a) Air-side free cooling/economiser cycle
- intake more outdoor air when its enthalpy (energy content) is lower than indoor air
- save energy in cooling systems by using natural cool outdoor air

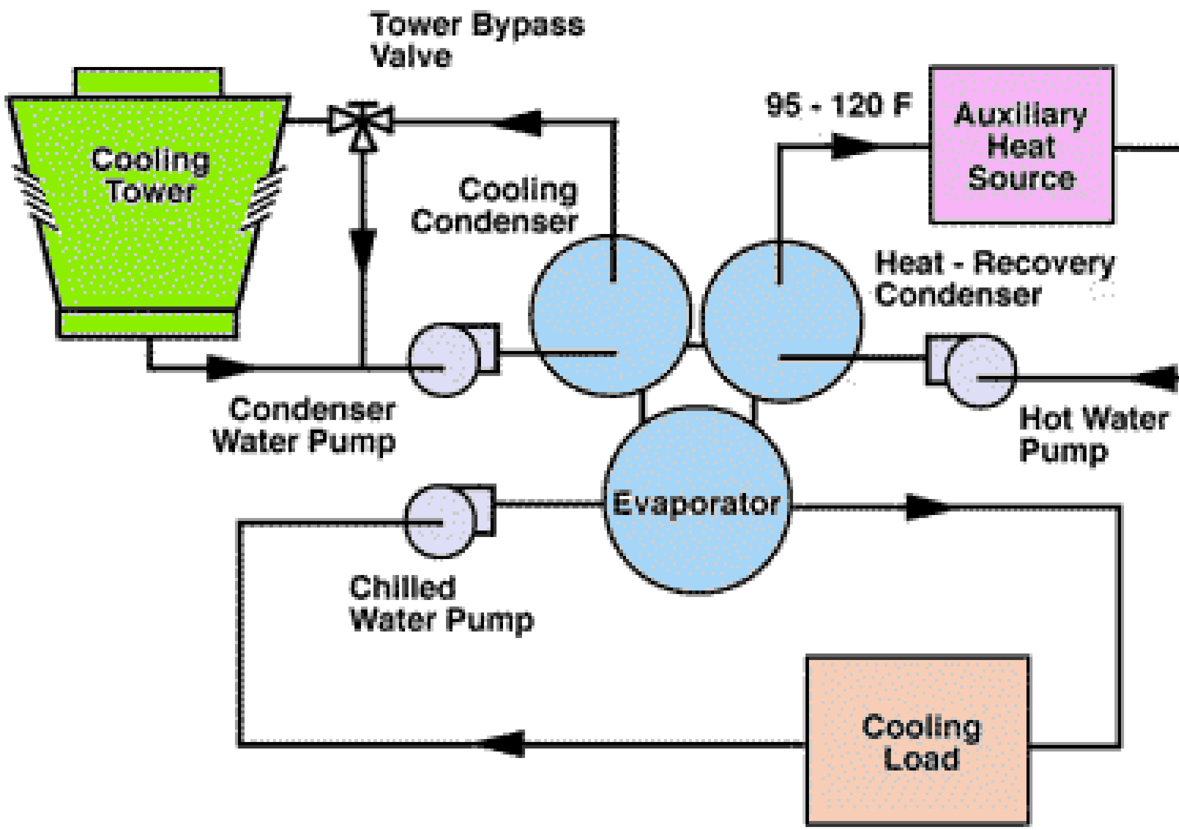


(b) Water-side free cooling or ‘free’ refrigeration
- chiller bypass when the system water can be cooled by ambient
- save energy in refrigeration or chiller plant

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

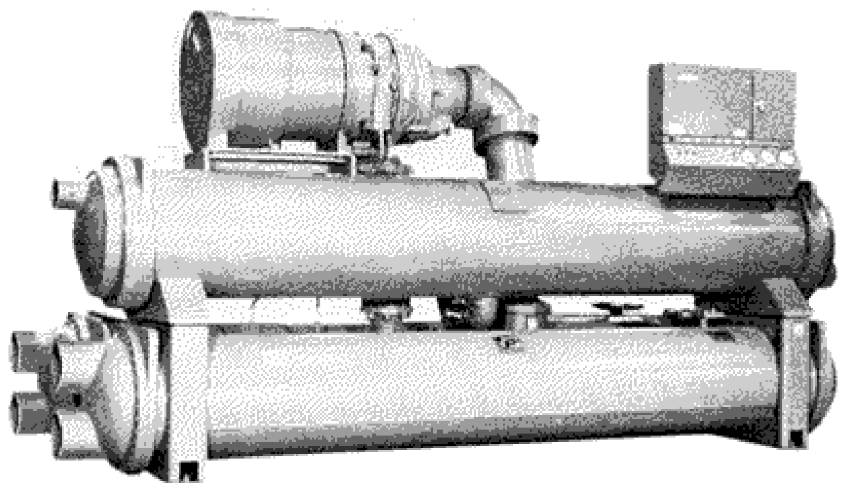
Waste heat recovery – e.g. double bundle heat recovery chiller

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

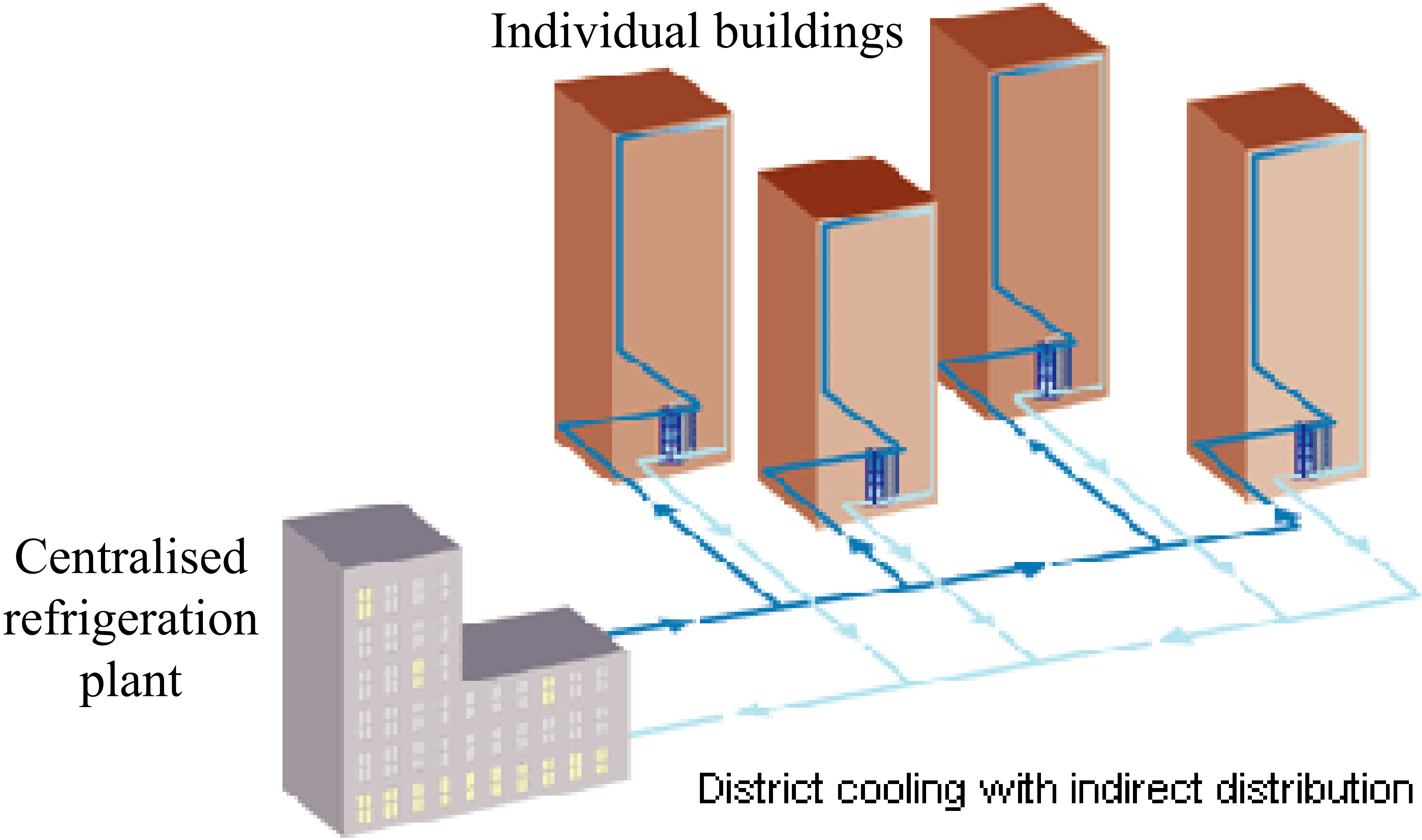


Double bundle heat recovery chiller

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

District cooling system (DCS)

Strategy: total energy approach

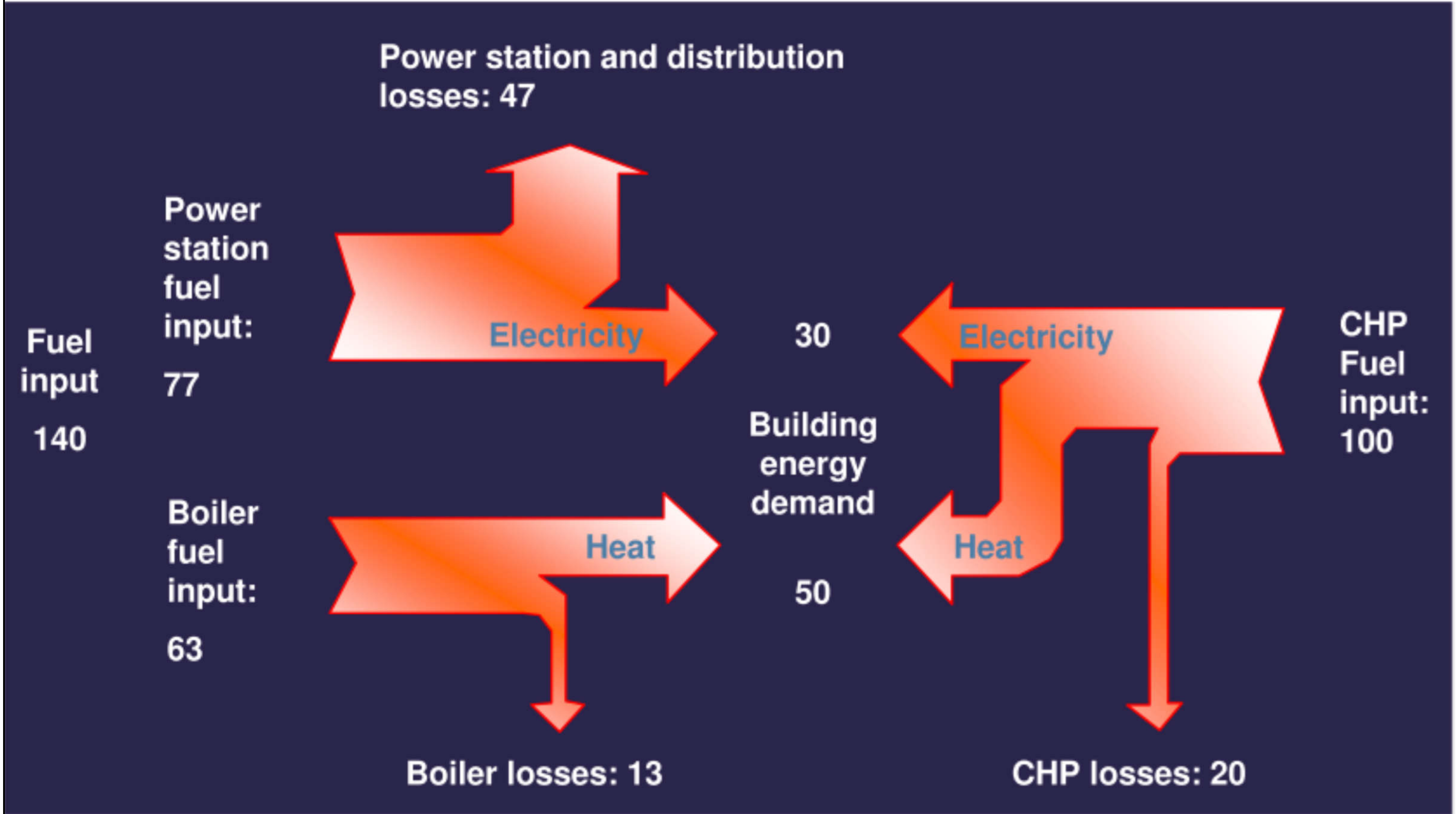


>> Do you know what are the advantages of DCS?

(*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)

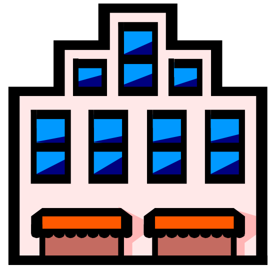
Combined heat and power (CHP), also known as cogeneration, reduces energy use by 30%



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

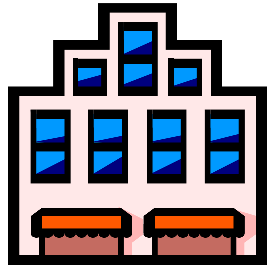
(Source: www.revival-eu.net)

Building Services Systems

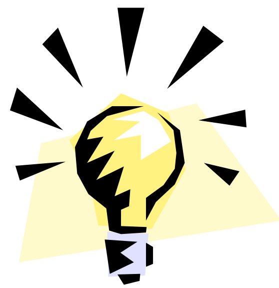


- HVAC energy efficiency can be improved by:
  - Effective zoning and space design
  - Correct sizing and selection of equipment
  - Proper operation and maintenance
  - Better control and monitoring
  - Energy awareness of occupants/building managers
- Good house-keeping and education
  - A very important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

Building Services Systems

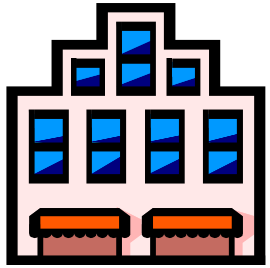


- Lighting systems
  - Have good potential for conserving electricity
  - Also contribute to HVAC load reduction
- General principles of energy efficient lighting*
  - Illumination is not excessive
  - Switching arrangements are designed
  - Provide illumination in an efficient manner

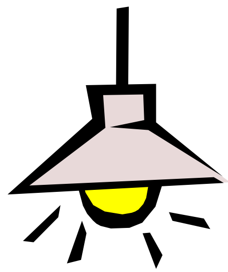


(*See also http://www.wbdg.org/resources/efficientlighting.php and http://www.wbdg.org/resources/daylighting.php)

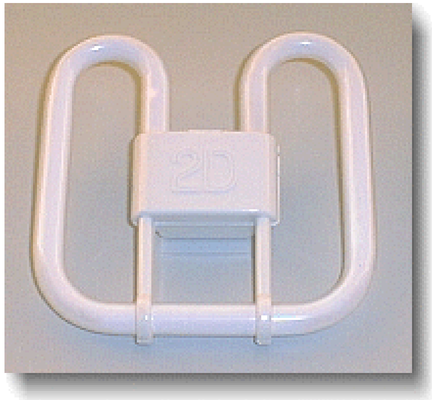
Building Services Systems



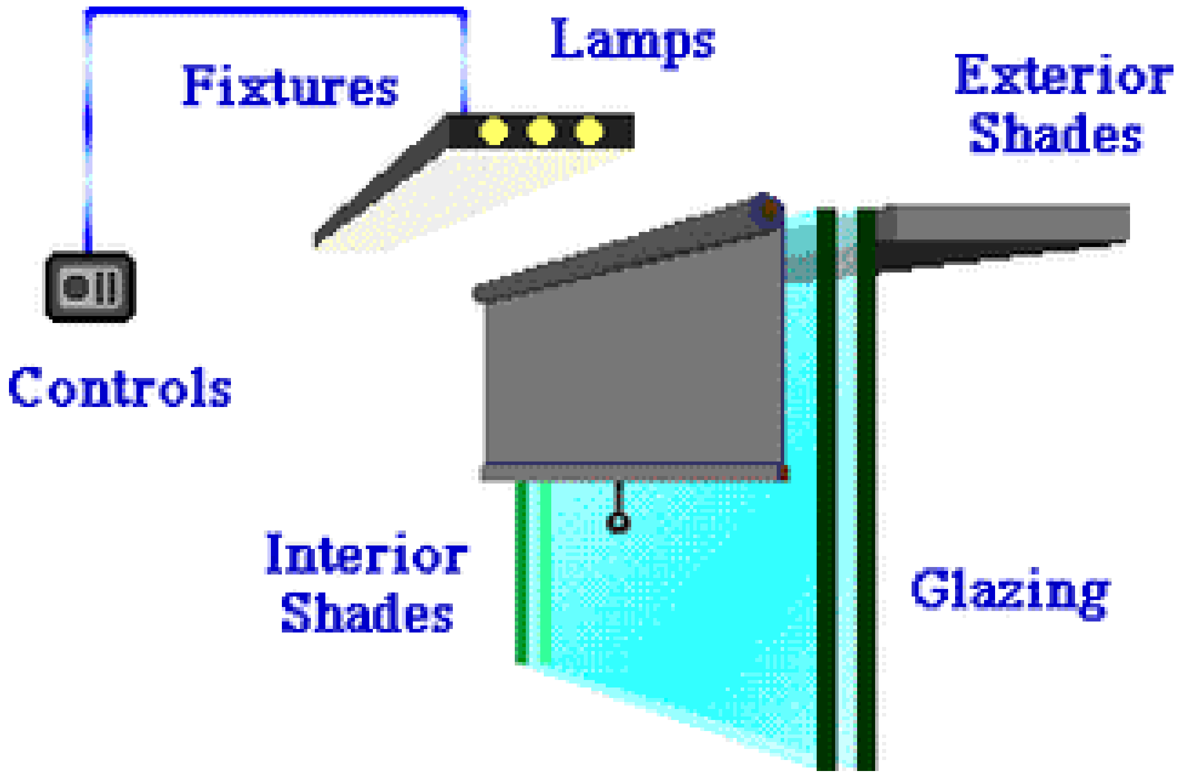
- Energy efficient lighting design strategies:
  - 1. Promotion of natural daylighting
  - 2. Use of energy efficient lamps and luminaires
  - 3. Switching and control of artificial light
  - 4. Combination of general and task lighting
  - 5. Electric lighting integrated with daylight
  - 6. Proper room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



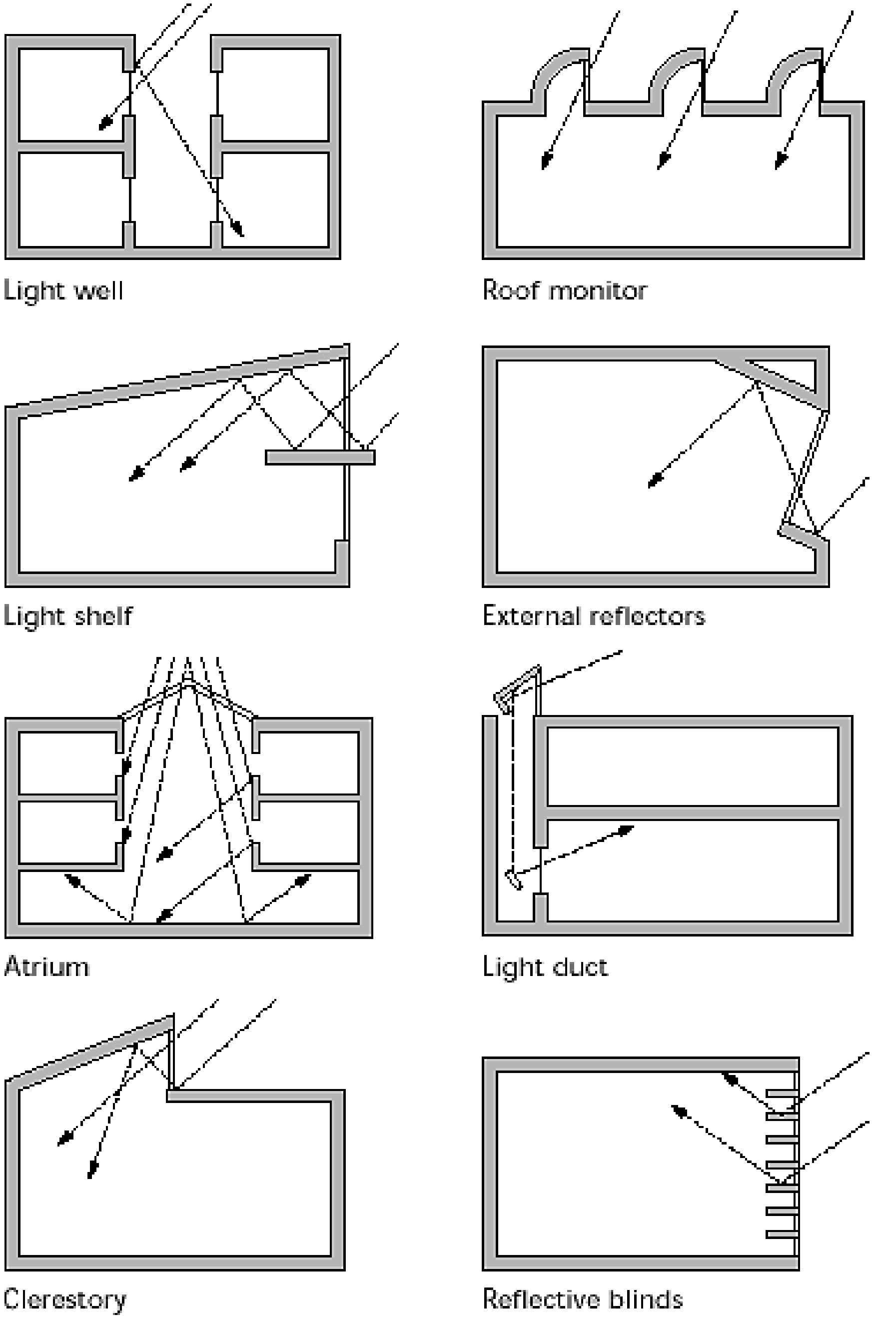
Energy efficient lighting design strategies

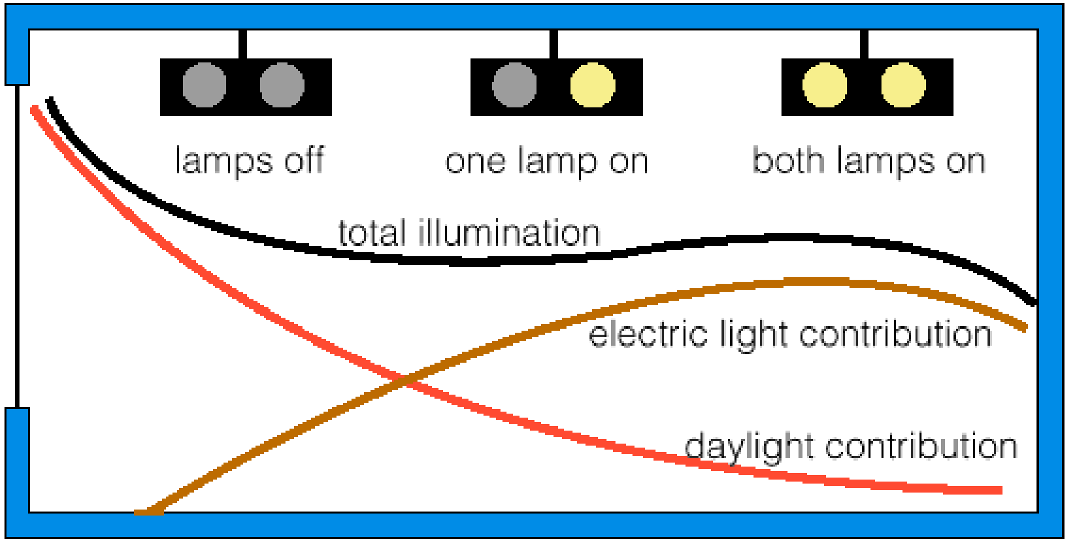


Energy efficient fittings (e.g. compact fluorescent lamps)



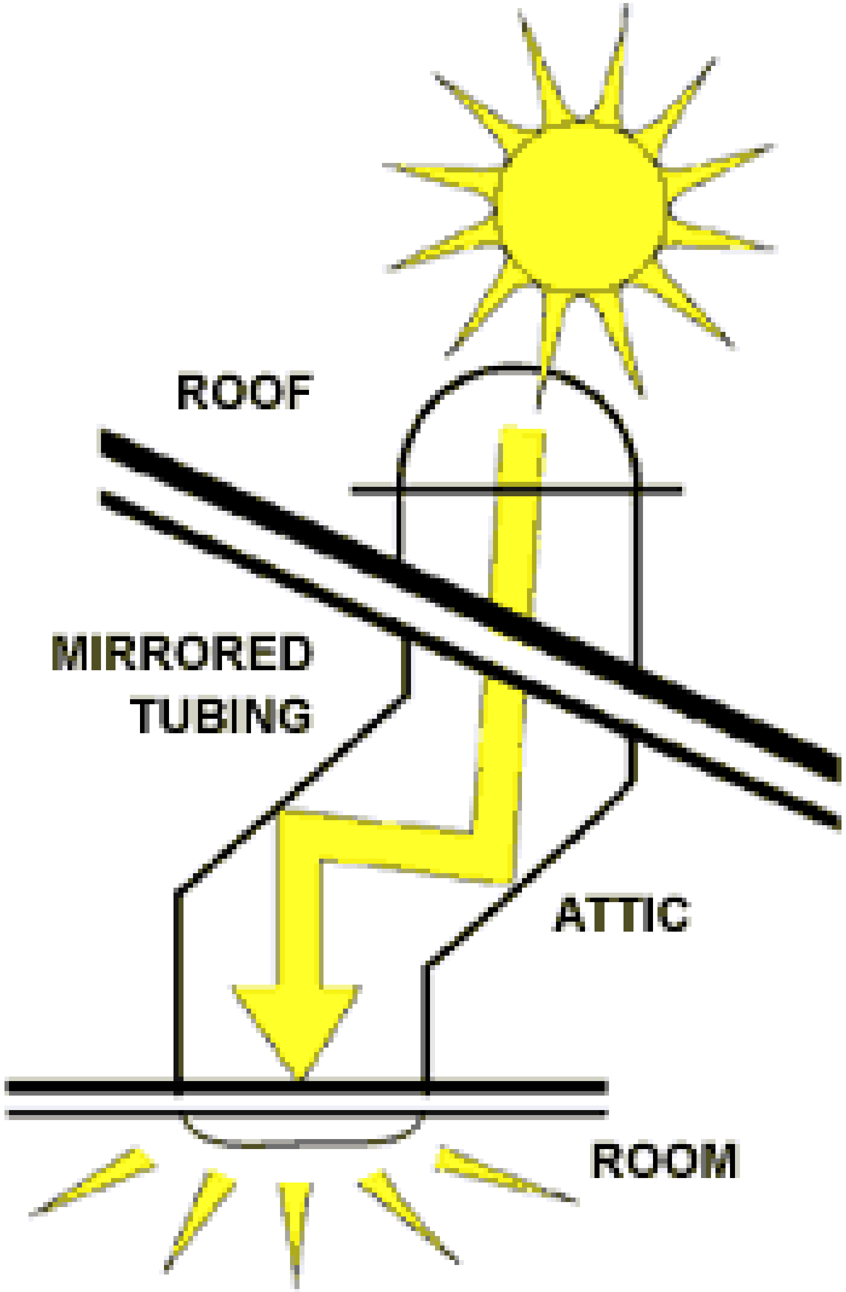
Lighting controls and interactions with windows

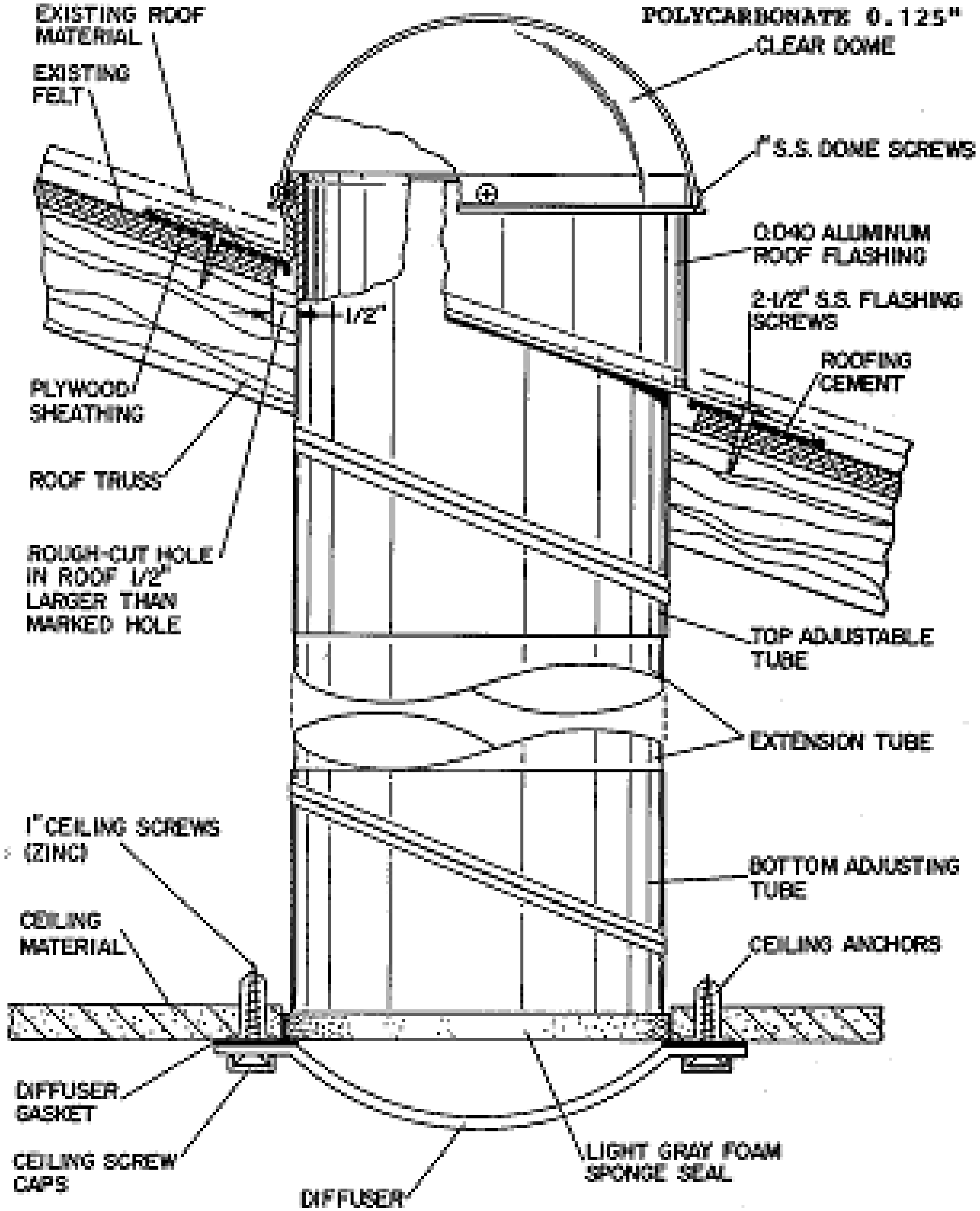




Daylighting design and control

Light tube system

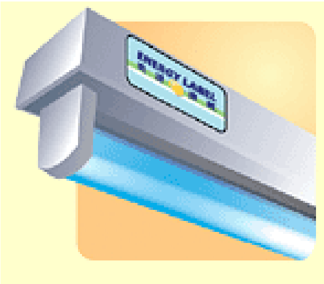




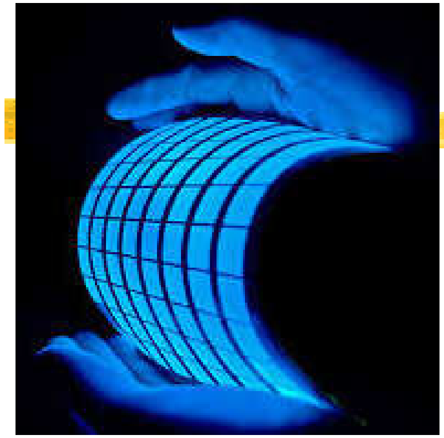
This can help to direct daylight into building interior

Building Services Systems

- 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



Evolution of lighting technology 照明技術的發展



Edison lamp 愛迪生燈

Incandescent lamp 白熾燈

Compact fluorescent lamp 緊湊型熒光燈

LED lamp 發光二極管燈

OLED lighting 有機發光二極體照明

Integrated controls for lighting luminaires

Vertically Integrated Design

Personal Control Features:

•Direct/ Indirect Pendant Luminaire

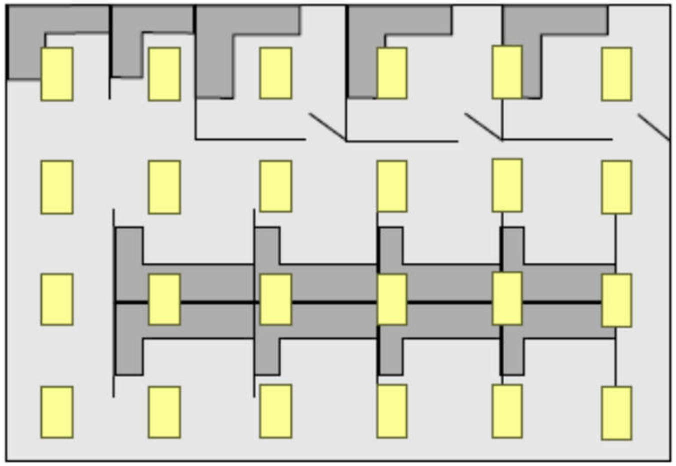
•Task light: 2T8-PS Dimmable EB (64W)/ 100%-5%

•Ambient light: 1T8-PS EB (31W)/ ON/OFF only

•Photocell Sensor built in

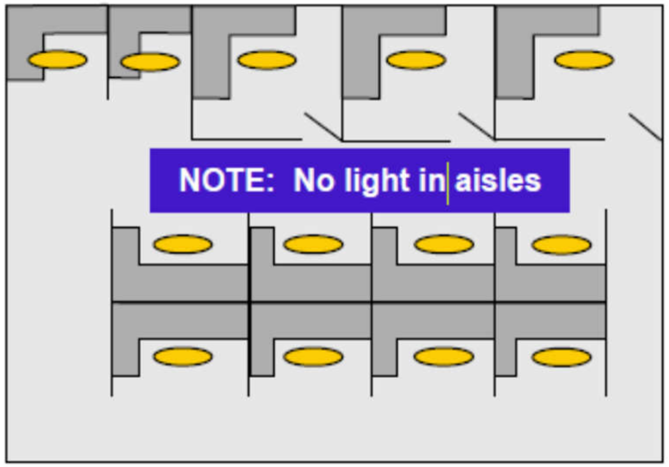
•Occupancy Sensor built in

Comparison to a Standard Troffer Layout:



- 2x4 Parabolics
- **24 Luminaires**
- 72 lamps
- **~2300 watts**

- Direct Indirect
- **13 Luminaires**
- 39 lamps
- **~1250 watts**



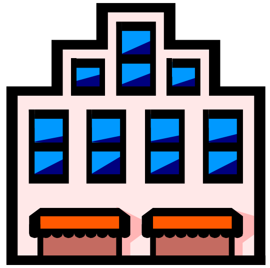
(Source: http://lightingdesignlab.com)

Building Services Systems

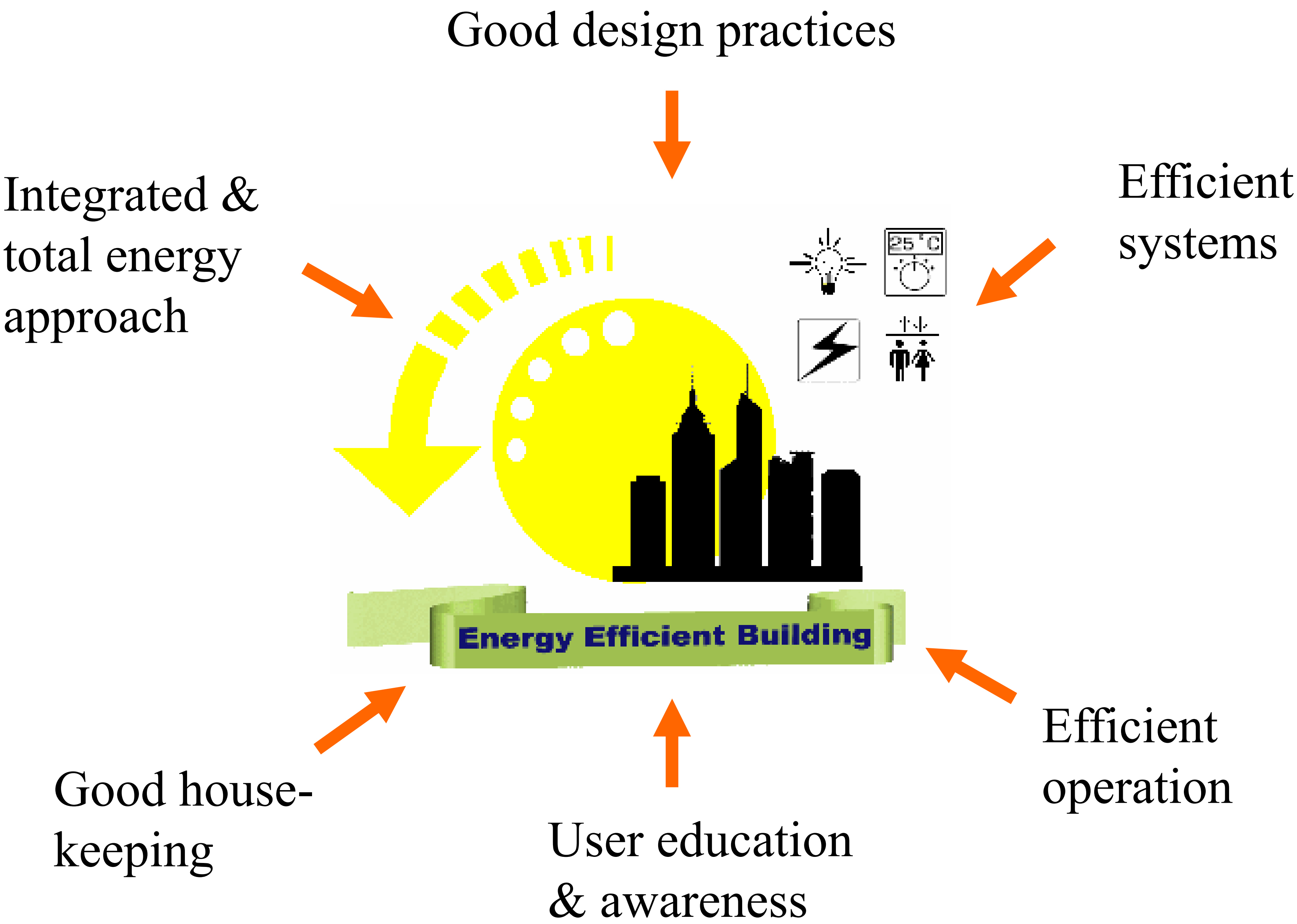
- Other building services systems
  - Electrical installation
  - Lifts and escalators
  - Water supply systems
  - Town gas supply system (cooking)

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

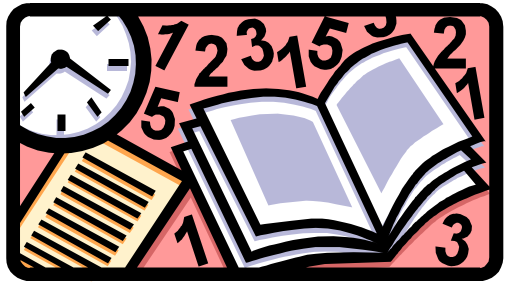
Building Services Systems



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

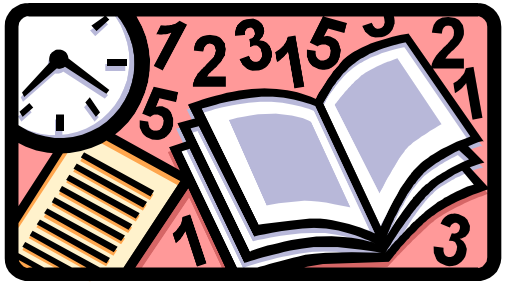

Good design practices
Integrated & total energy approach
Efficient systems
25°C
Energy Efficient Building
Good house-keeping
User education & awareness
Efficient operation

Further Reading



- Checklist for Building Energy Efficiency
  - http://ibse.hk/BEE-checklist.pdf
    - Architecture
    - HVAC
    - Electrical services
    - Lighting installations
    - Lifts and escalators
    - Plumbing and drainage
    - Building management

Further Reading



- Public Education: Education Kit [EMSD] https://www.emsd.gov.hk/en/about_us/public_education/education_kit/
  - Energy Efficiency
  - Energy Efficient Building
- HK EE Net 香港節能網 http://ee.emsd.gov.hk/