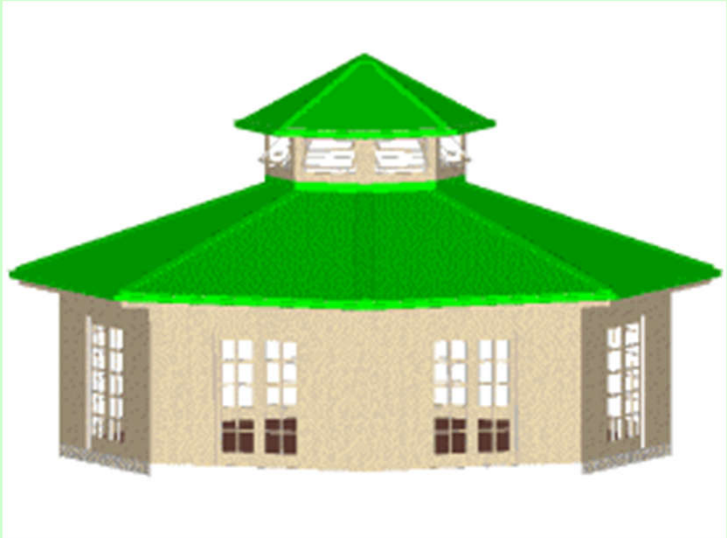

Sustainable Building Concepts (II)

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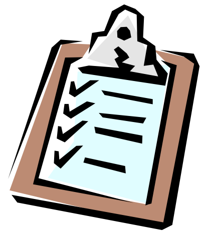
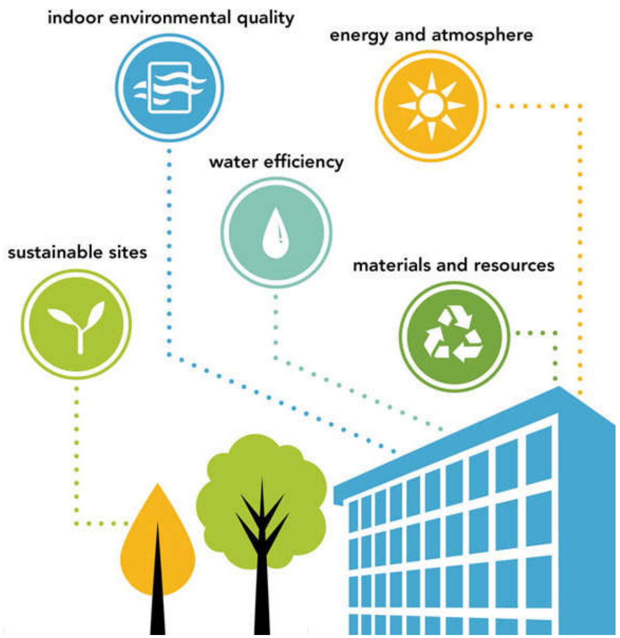
Contents



- Urban and site design
- Energy efficiency
- Renewable energy
- Building materials
- Water issues
- Indoor environment
- Integrated building design

Design strategies

- 1. Sustainable site
  - Site selection, landscaping, building placement
- 2. Energy and atmosphere
  - Energy sources, mechanical systems and controls
- 3. Water efficiency
- 4. Materials and resources
  - Design, material selection
- 5. Indoor environmental quality



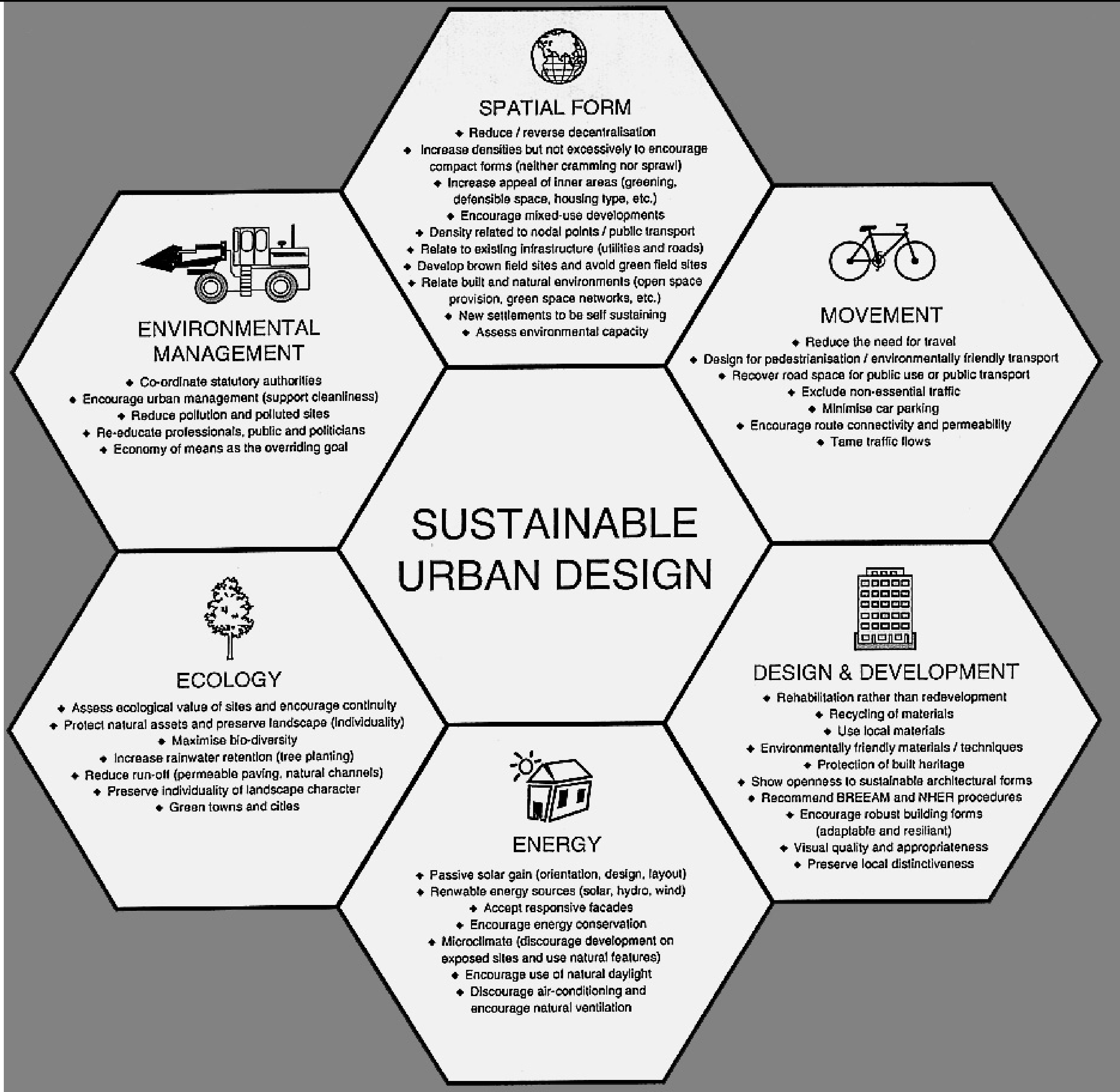
(See also: Green building design strategies http://ibse.hk/GB_design_strategies.pdf)

Urban and site design

- Planning of development at different *scales*
  - Building, blocks, district, city/town, region
- Good urban design ensures economically viable places and spaces that are:
  - Resource efficient
  - Adaptable
  - Durable
  - Inclusive
  - Fit for purpose

Urban and site design

- Sustainable urban design should consider:
  - Spatial form
  - Movement
  - Design & development
  - Energy
  - Ecology
  - Environmental management
- Goal: to create livable cities


SPATIAL FORM
Reduce / reverse decentralisation
Increase densities but not excessively to encourage compact forms (neither cramming nor sprawl)
Increase appeal of inner areas (greening, defensible space, housing type, etc.)
Encourage mixed-use developments
Density related to nodal points / public transport
Relate to existing infrastructure (utilities and roads)
Develop brown field sites and avoid green field sites
Relate built and natural environments (open space provision, green space networks, etc.)
New settlements to be self sustaining
Assess environmental capacity
ENVIRONMENTAL MANAGEMENT
Co-ordinate statutory authorities
Encourage urban management (support cleanliness)
Reduce pollution and polluted sites
Re-educate professionals, public and politicians
Economy of means as the overriding goal
MOVEMENT
Reduce the need for travel
Design for pedestrianisation / environmentally friendly transport
Recover road space for public use or public transport
Exclude non-essential traffic
Minimise car parking
Encourage route connectivity and permeability
Tame traffic flows
SUSTAINABLE URBAN DESIGN
ECOLOGY
Assess ecological value of sites and encourage continuity
Protect natural assets and preserve landscape (individuality)
Maximise bio-diversity
Increase rainwater retention (tree planting)
Reduce run-off (permeable paving, natural channels)
Preserve individuality of landscape character
Green towns and cities
DESIGN & DEVELOPMENT
Rehabilitation rather than redevelopment
Recycling of materials
Use local materials
Environmentally friendly materials / techniques
Protection of built heritage
Show openness to sustainable architectural forms
Recommend BREEAM and NHER procedures
Encourage robust building forms (adaptable and resiliant)
Visual quality and appropriateness
Preserve local distinctiveness
ENERGY
Passive solar gain (orientation, design, layout)
Renwable energy sources (solar, hydro, wind)
Accept responsive facades
Encourage energy conservation
Microclimate (discourage development on exposed sites and use natural features)
Encourage use of natural daylight
Discourage air-conditioning and encourage natural ventilation

Urban and site design

- Basic principles
  - 1. Increase local self-sufficiency
  - 2. Concern for human needs (social+community)
  - 3. Develop energy-efficient movement networks
  - 4. The open space network (公共空間)
  - 5. Linear concentration
  - 6. Energy strategy
  - 7. Water strategy

Urban and site design

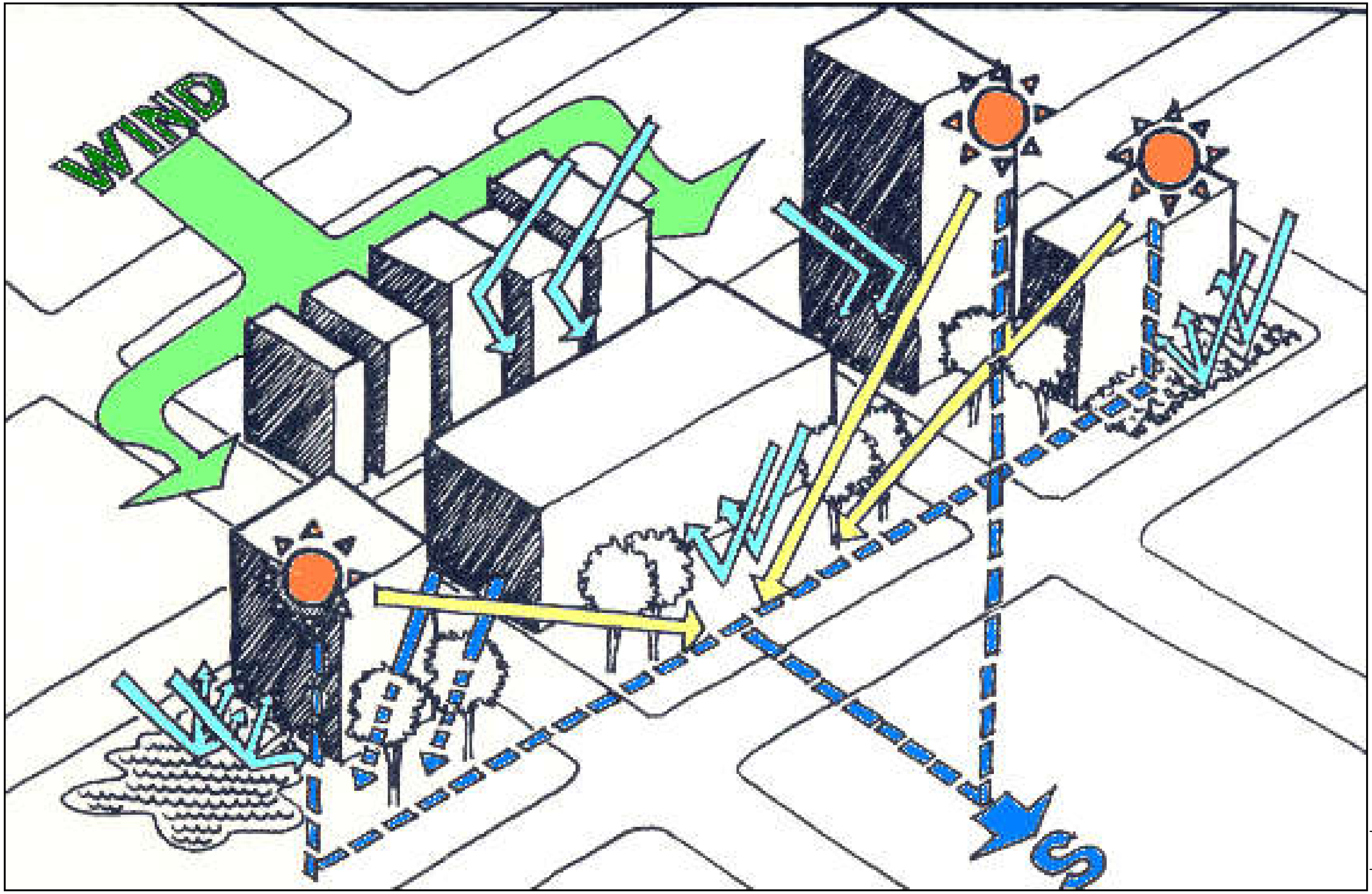
- Design issues:
  - Site selection (e.g. prefer brownfield site 棕地*)
  - Promote efficient movement network & transport
  - Control & reduce noise impacts
  - Optimise natural lighting & ventilation
  - Design for green space & landscape
  - Minimise disturbance to natural ecosystems
  - Enhance community values

[* Brownfield sites are abandoned or underused industrial and commercial facilities available for re-use.]

Site analysis and environmental factors

風
Wind

光
Light



水
Water

物
Matter

Site analysis and understanding of the environmental factors is important

Urban and site design

- <u>Design strategies</u>
  - Integrate design with public transportation
    - Quite successful in Hong Kong
  - Promote mixed use development
    - Such as residential + commercial
  - Respect topographical contours (land forms)
  - Preserve local wildlife and vegetation
  - Make use of landscaping and planting (green space) to modify the local micro-climate

Urban and site design

- Planning Cities for People: 8 principles
  - 1. Walk: Develop neighborhoods that promote walking
  - 2. Cycle: Prioritize bicycle networks
  - 3. Connect: Create dense networks of streets and paths
  - 4. Transit: Support high-quality transit
  - 5. Mix: Zone for mixed-use neighborhoods
  - 6. Densify: Match density to transit capacity
  - 7. Compact: Create compact regions with short commutes
  - 8. Shift: Increase mobility by regulating parking and road use

(Source: Planning Cities for People: A Guide to Prosperous, Low-Carbon Urbanization https://energyinnovation.org/wp-content/uploads/2014/11/Planning-Cities-for-People.pdf)

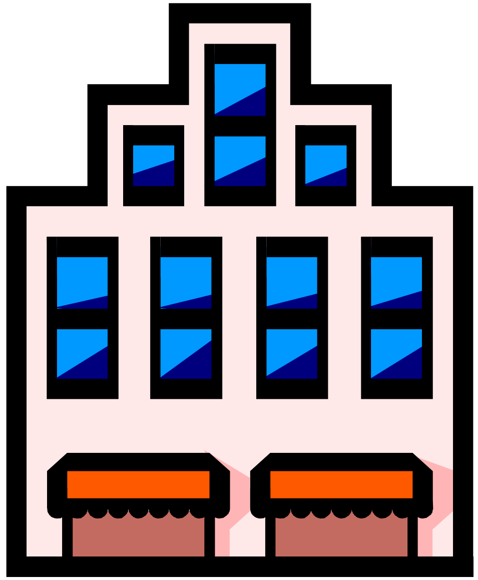
The 8 Principles for better streets and better cities (with transport-oriented development, TOD)

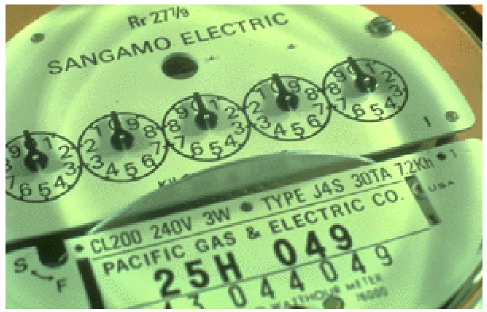
(Ref: Cities for People in Practice https://energyinnovation.org/wp-content/uploads/2015/01/Cities-for-People-in-Practice-2015.pdf)

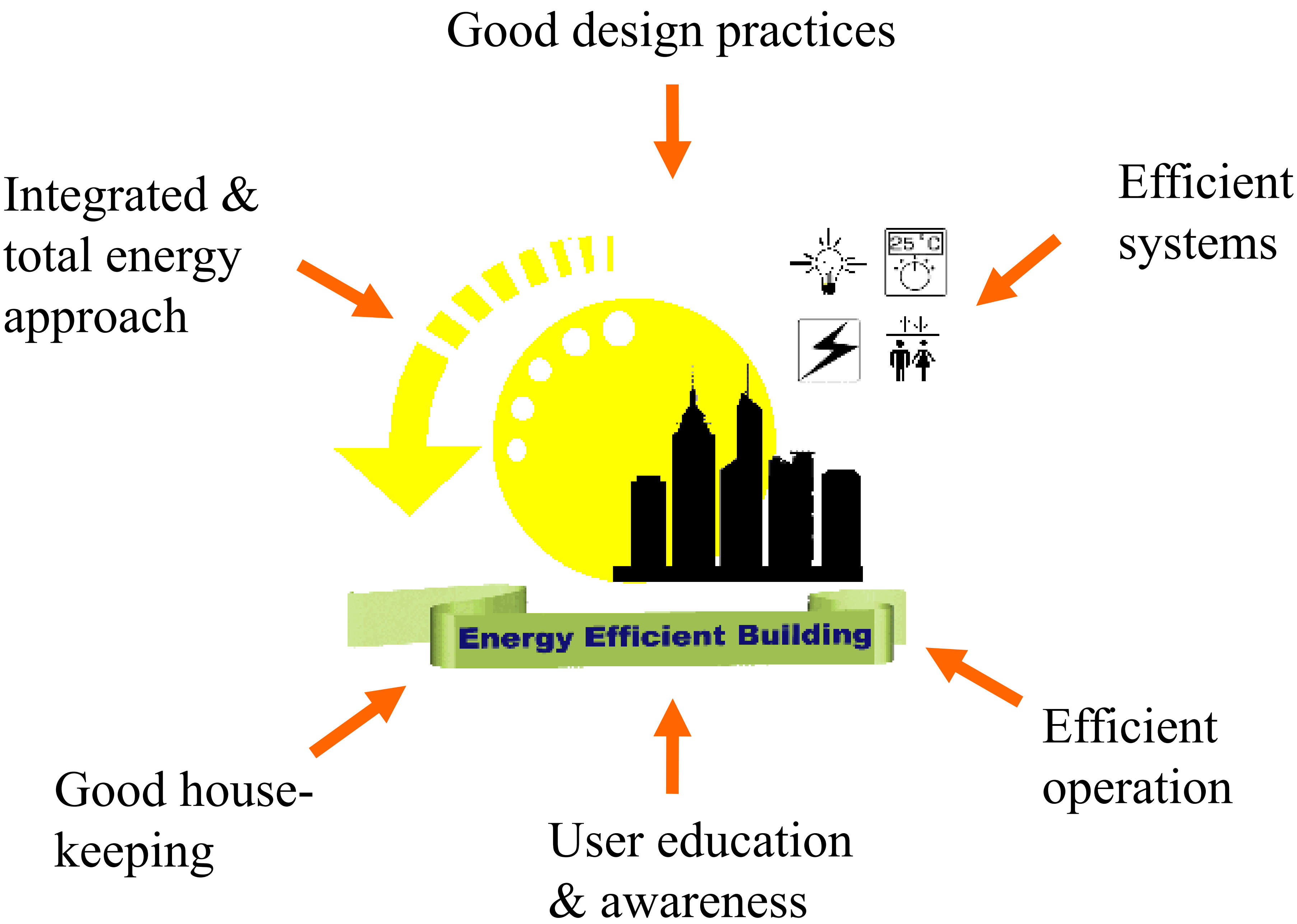
(Source: Principles for Transport in Urban Life https://www.itdp.org/2014/03/28/principles-for-transport-in-urban-life/)

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



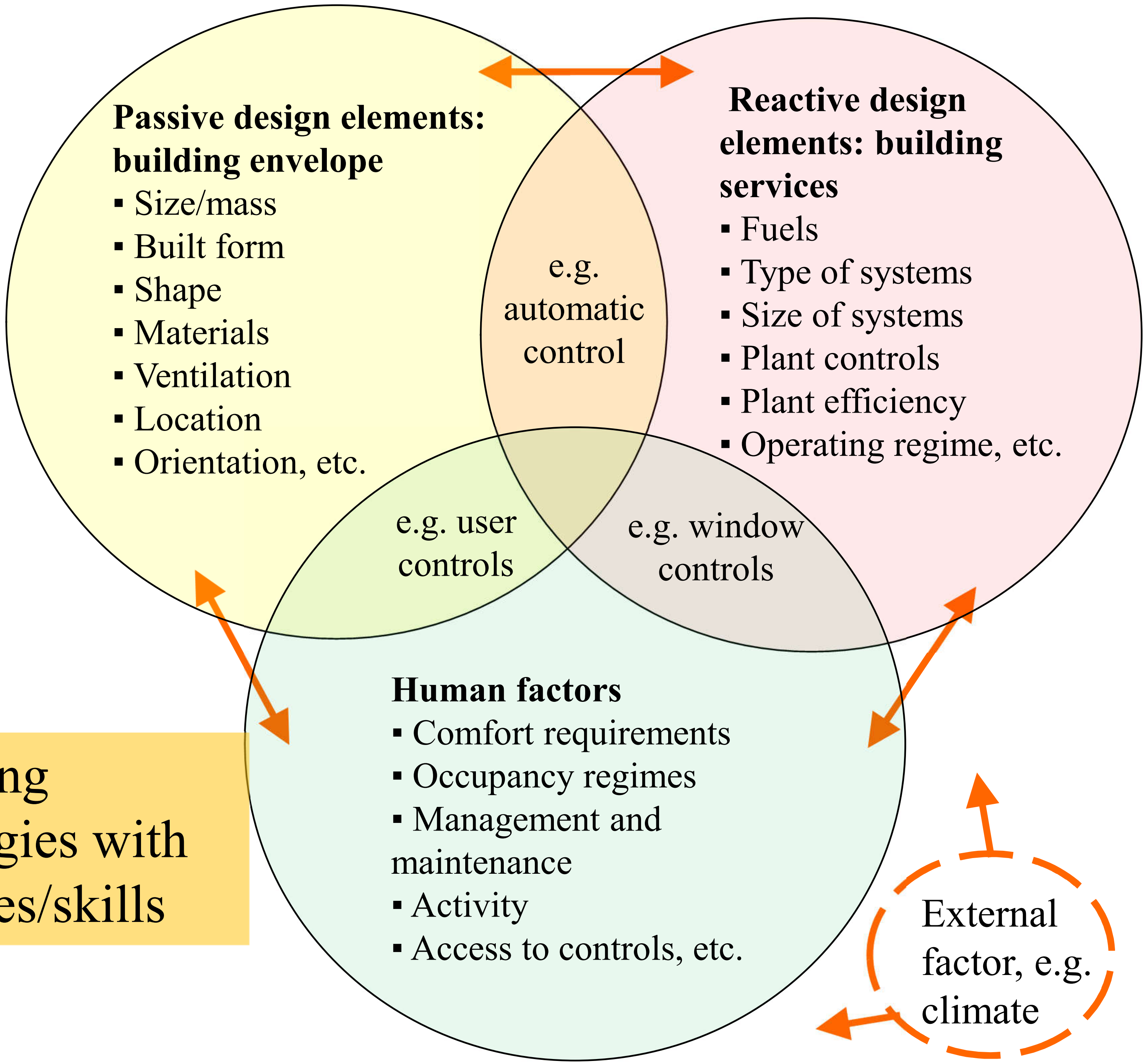




Good design practices
Integrated & total energy approach
Efficient systems
25 °C
Energy Efficient Building
Good house-keeping
User education & awareness
Efficient operation

Key factors influencing building energy consumption

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



Combining technologies with techniques/skills

Energy efficiency

被動式設計

- Promote *passive design* and *natural ventilation*
  - e.g. bioclimatic buildings, passive cooling/heating

- Adopt energy efficient *building services systems*
  - Lighting, air-conditioning, electrical, lifts
- Study & optimize *thermal & energy performance*
  - e.g. by computer simulation or energy audit
- Must also ensure *efficient operation and management* of the building
  - User education & awareness, good housekeeping

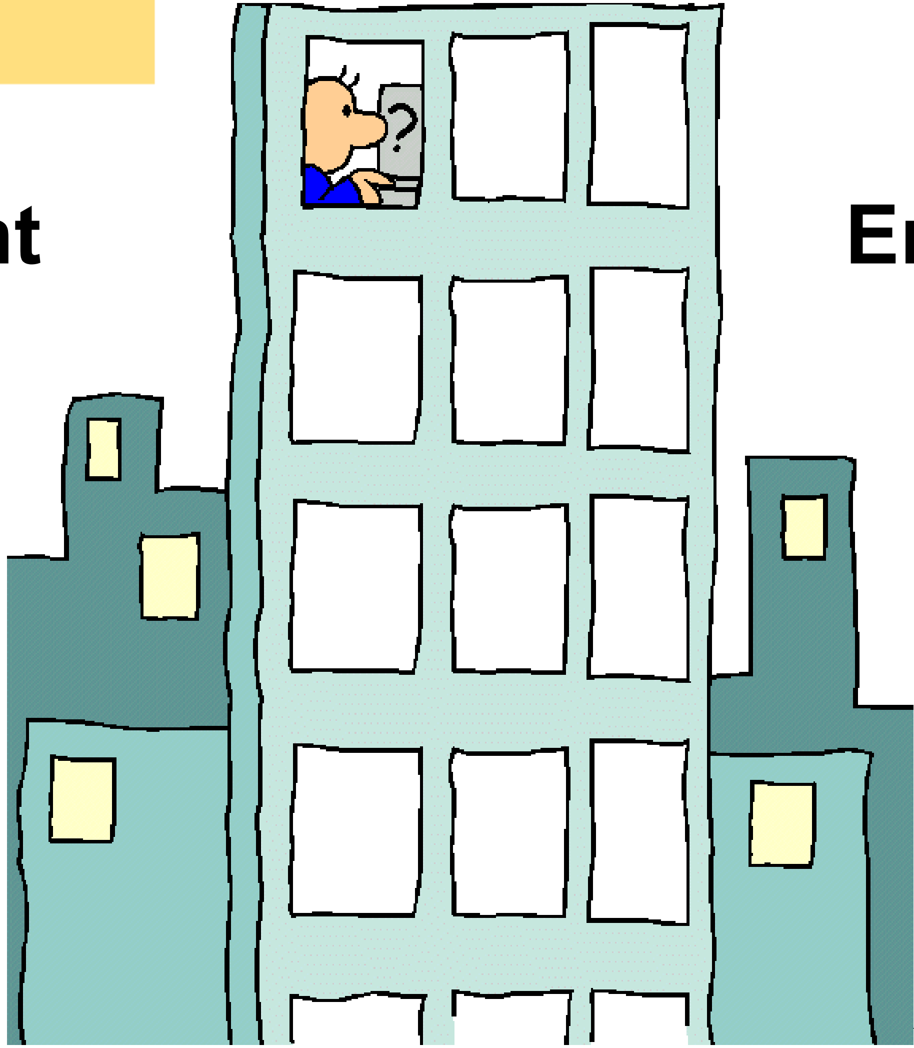
Passive design principles of energy efficient building

Respond effectively to local climate and site conditions in order to maximise comfort for the occupants

被動式設計

Shelter

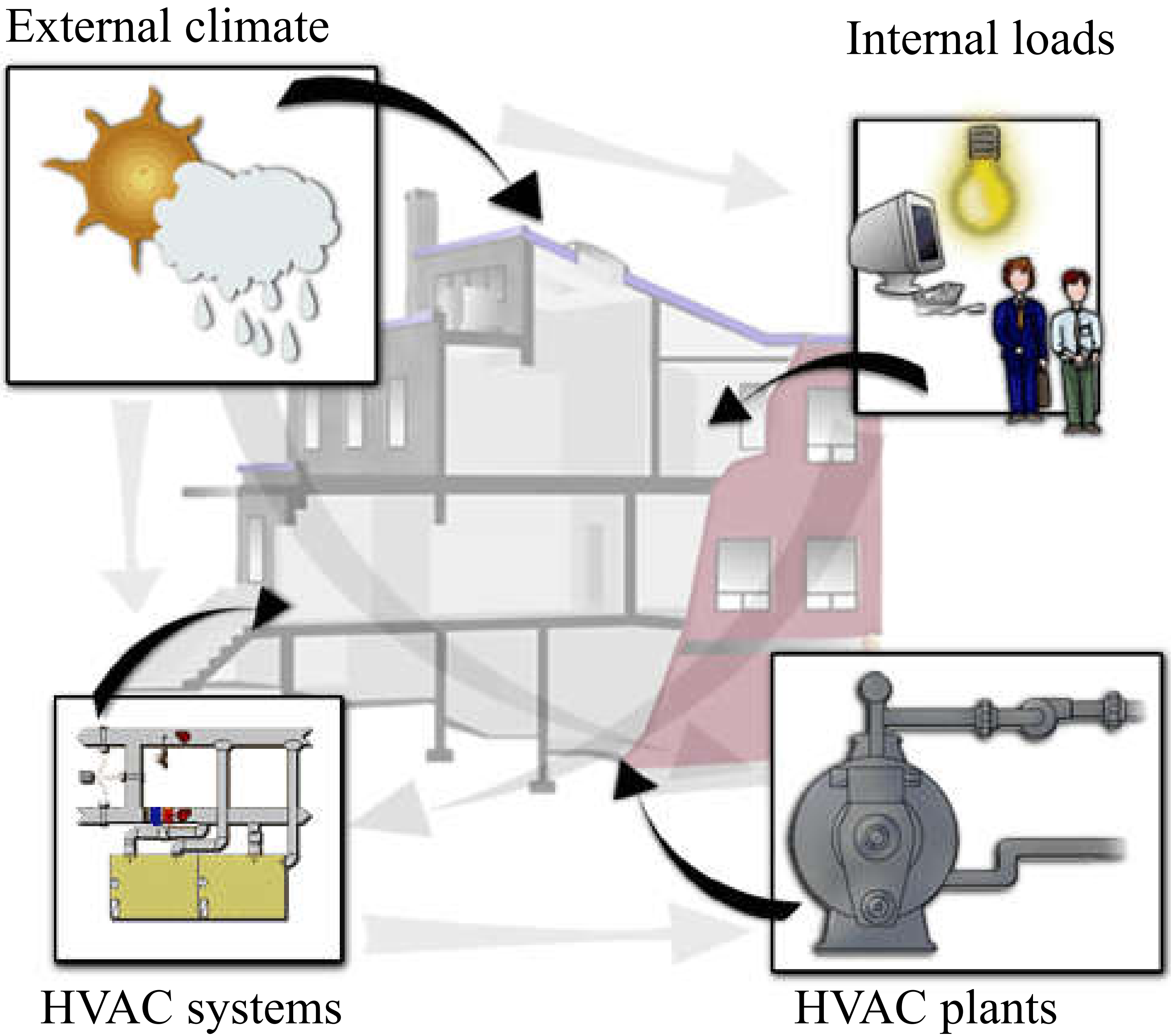
Outdoor Environment



Human Environment

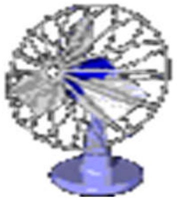
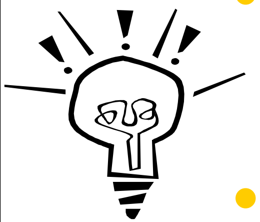
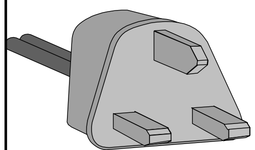
Energy supply to the building

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



HVAC = heating, ventilation and air conditioning

Energy efficiency

- Design strategies:

  - Minimise thermal loads & energy requirements
    - e.g. by reducing heat gains from equipment

  - Optimise window design & fabric thermal storage
    - Integrate architectural & engineering design
  - Promote efficiency in building services systems

    - Use of heat recovery & free cooling methods
    - Energy efficient lighting design & control
    - High-efficiency mechanical & electrical systems

  - Adopt total energy approach (e.g. district cooling, combined heat & power)

Energy efficiency

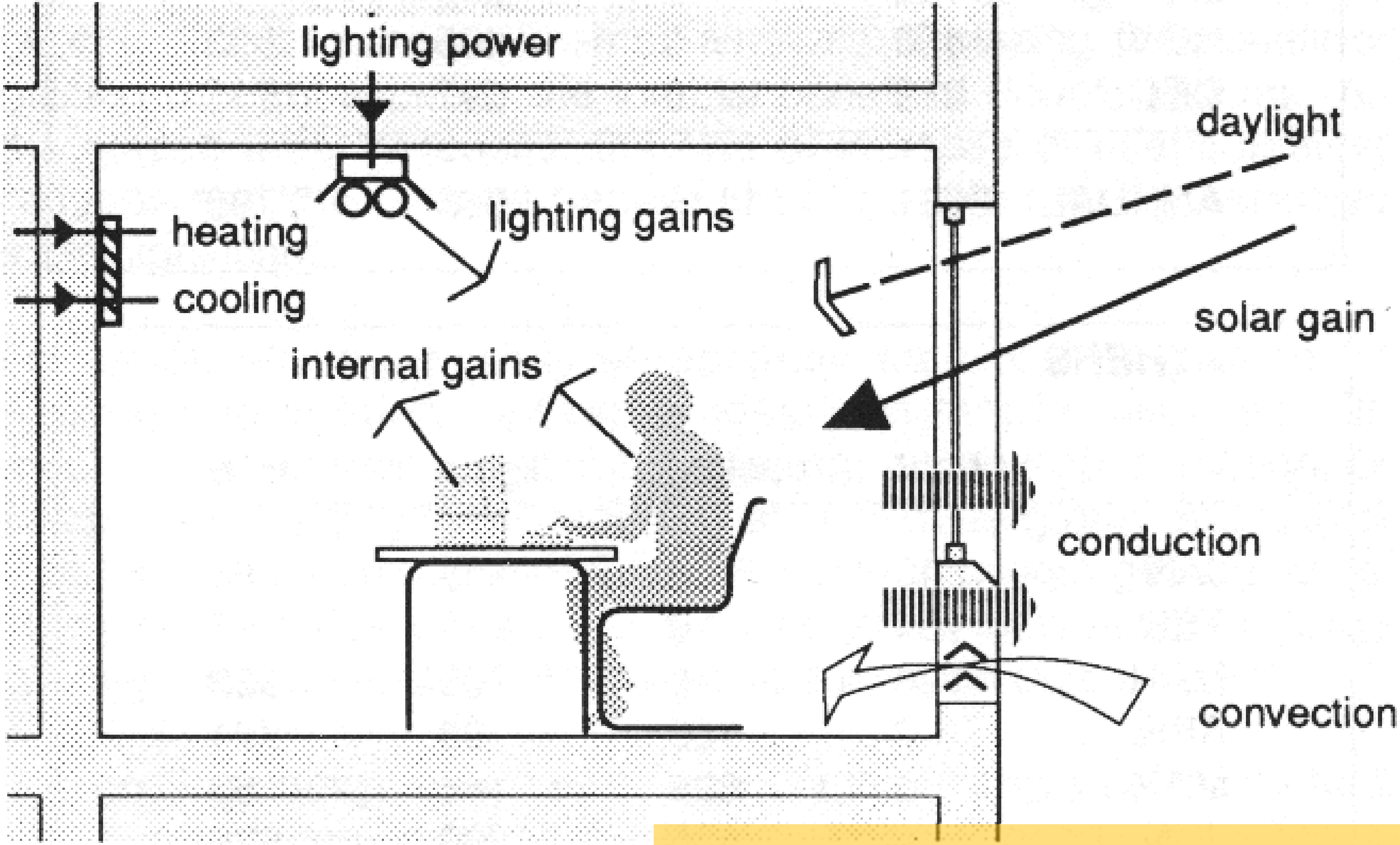
- Video: Energy 101: Energy Efficient Commercial Buildings (4:19)

  - http://youtu.be/5VMXL3lEYTI
  - Learn how commercial buildings can incorporate whole-building design to save energy and money while enhancing performance and comfort.
  - This video highlights several energy-saving features of the Research Support Facility at the Energy Department's National Renewable Energy Laboratory—a model for high-performance office building design.

(More info: The Design-Build Process for the Research Support Facility https://www.nrel.gov/docs/fy12osti/51387.pdf)

Thermal energy balance in a building space

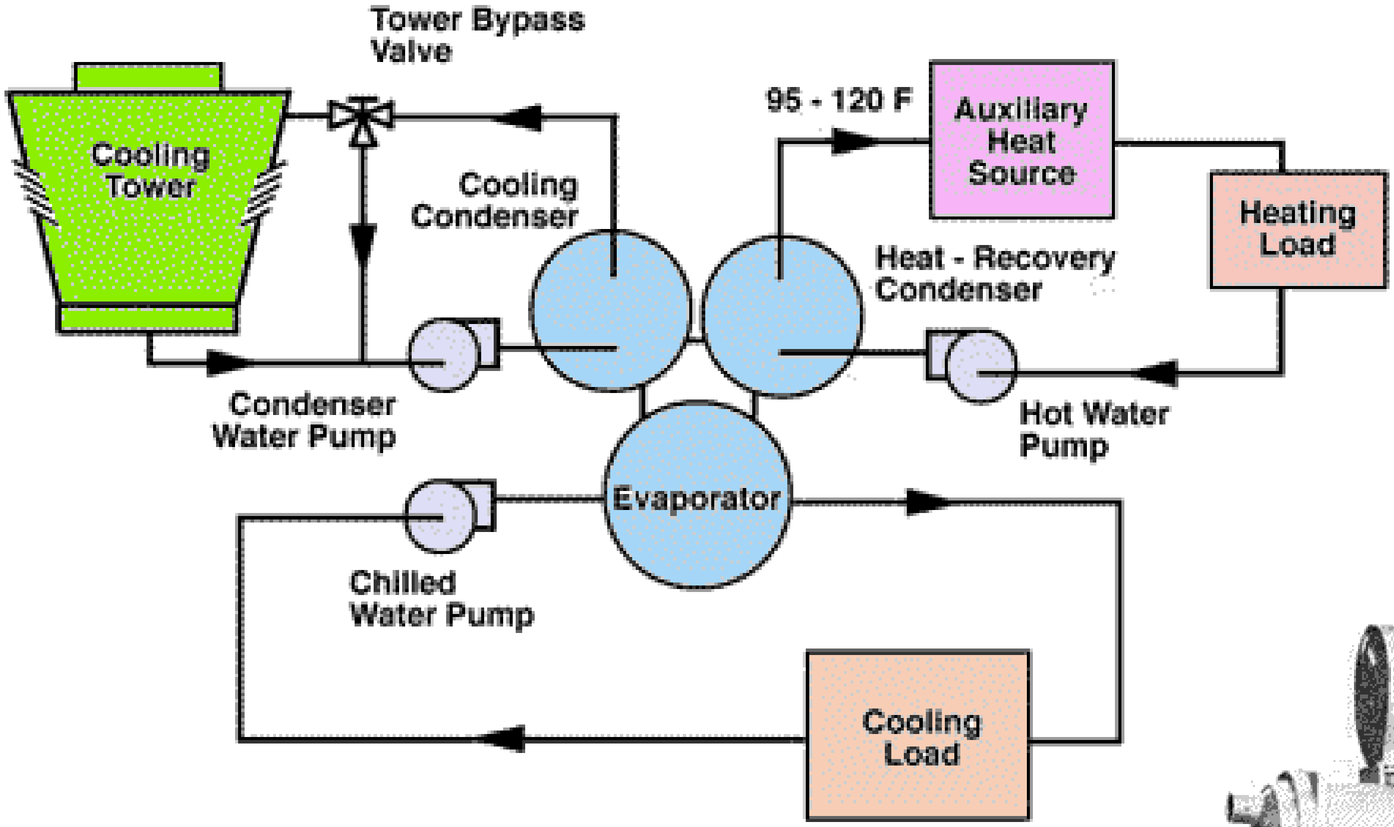
Strategy: reduce thermal loads



Strategy: optimise building envelope

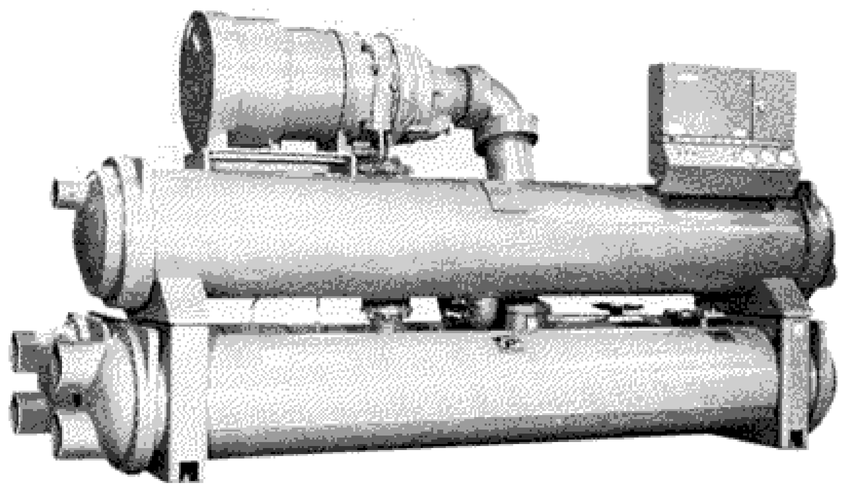
Waste heat recovery – e.g. double bundle heat recovery chiller

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

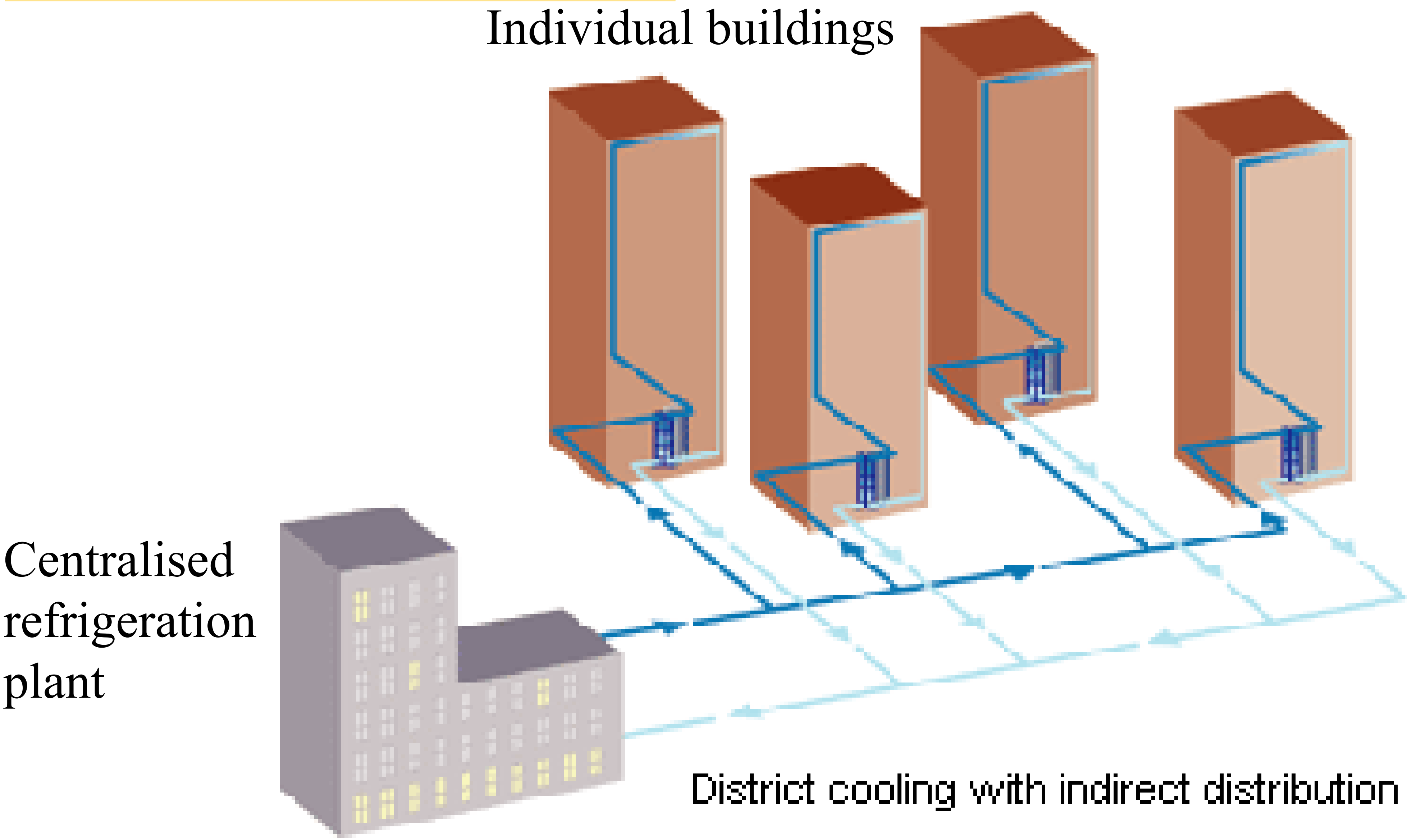


Double bundle heat recovery chiller

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

District cooling system (DCS)

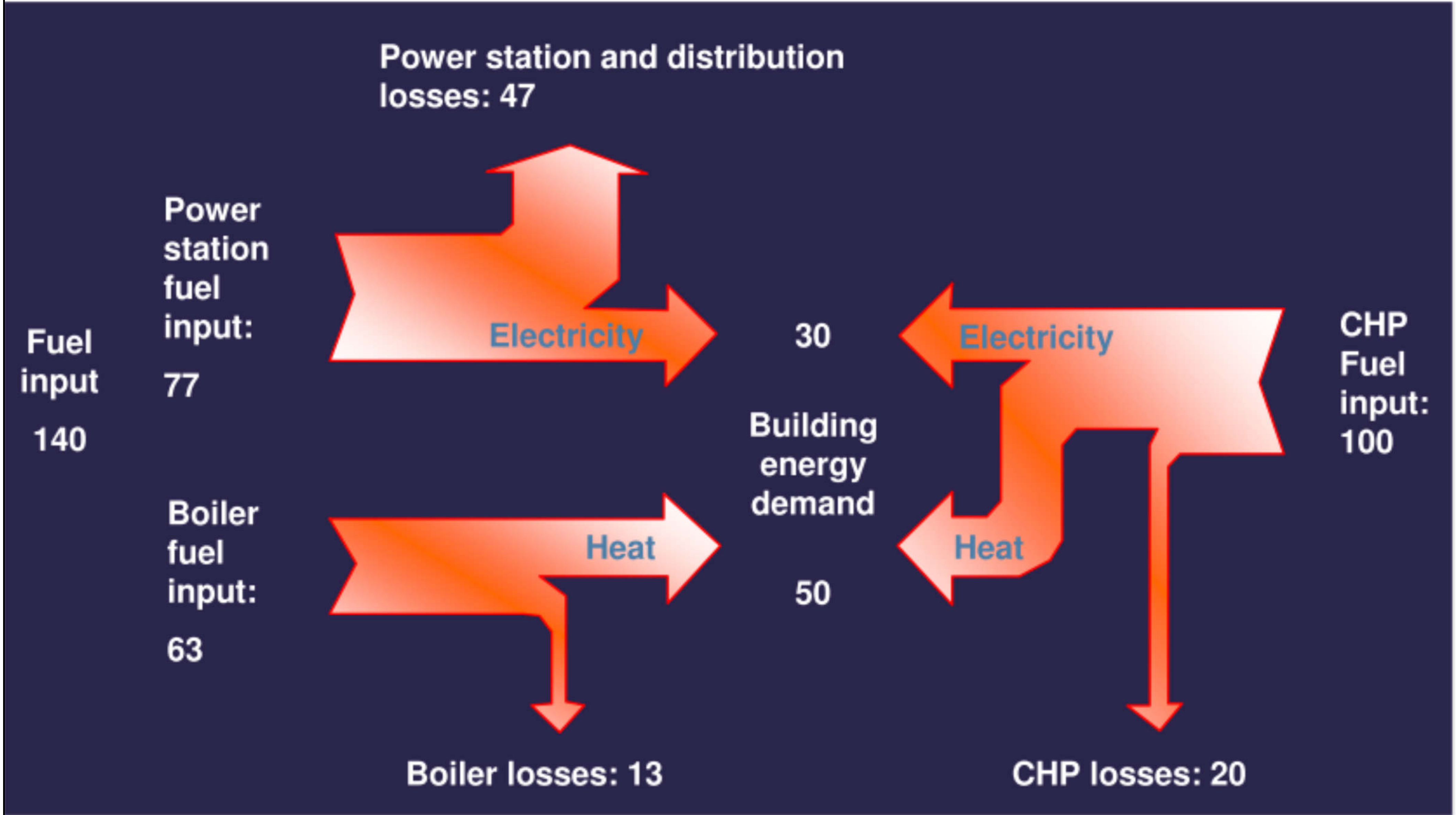
Strategy: total energy approach



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

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

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)

Renewable energy

Definitions

- Energy that occurs naturally and repeatedly on earth and can be harnessed for human benefit
- Such as solar, wind, biomass, energy from waste, geothermal, hydro, wave and tidal, ocean thermal
- Most renewables are derived from the SUN

  - Direct use of solar energy for heating or electricity
  - Indirect forms (e.g. wind, waves, running water)

可再生能源

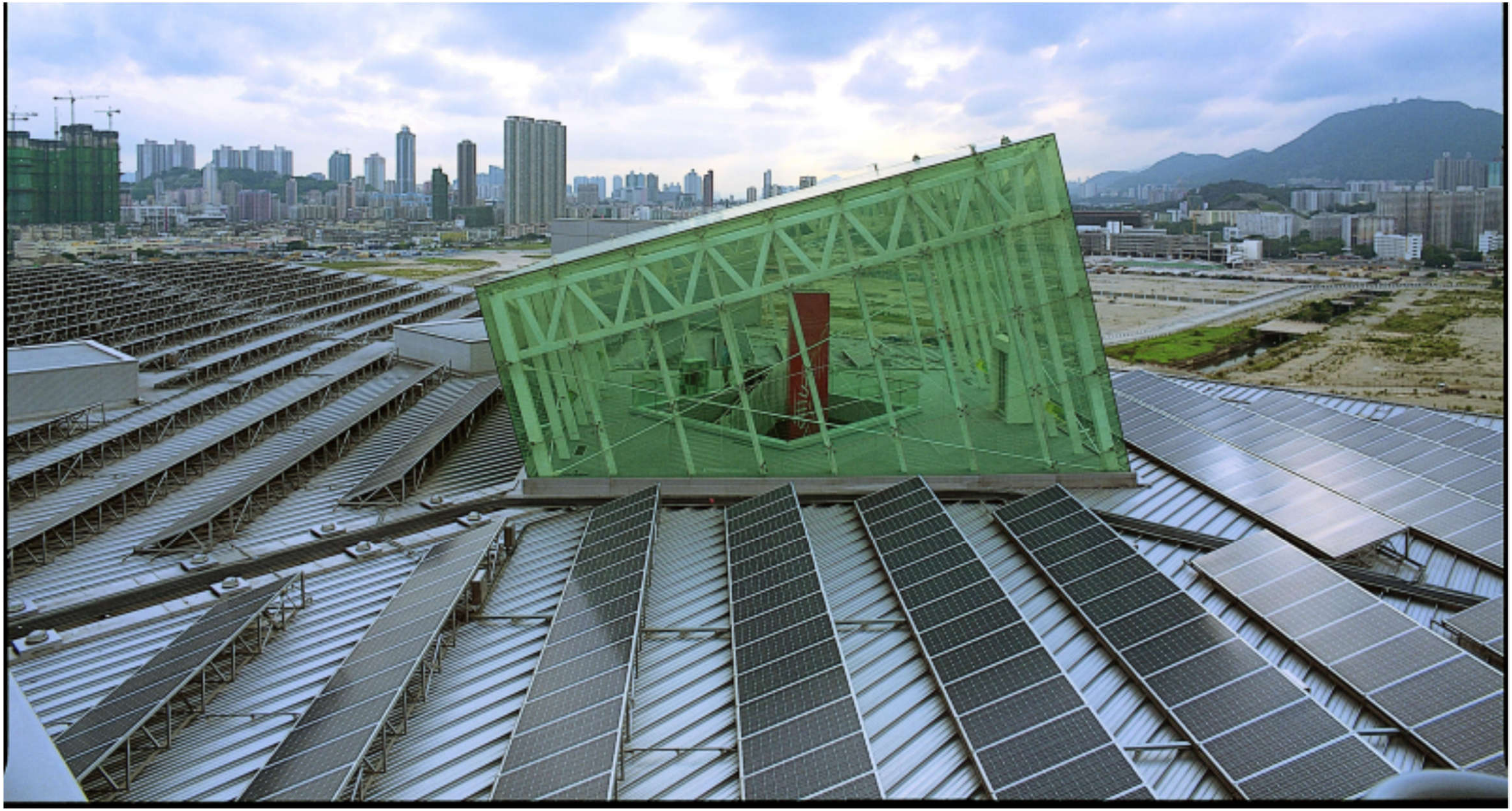


Solar thermal systems in Hong Kong

Solar heating for a swimming pool complex in Kwai Chung (313 sq.m solar collectors)

Solar hot water system at Sheung Shui Slaughter House (882 sq.m solar collectors)

Solar photovoltaic system in Hong Kong



A 350 kW solar photovoltaic (PV) installation installed on the roof of the EMSD Headquarters in Kowloon Bay (2,300 PV modules with a total area of 3,180 sq.m) [Source: EMSD]

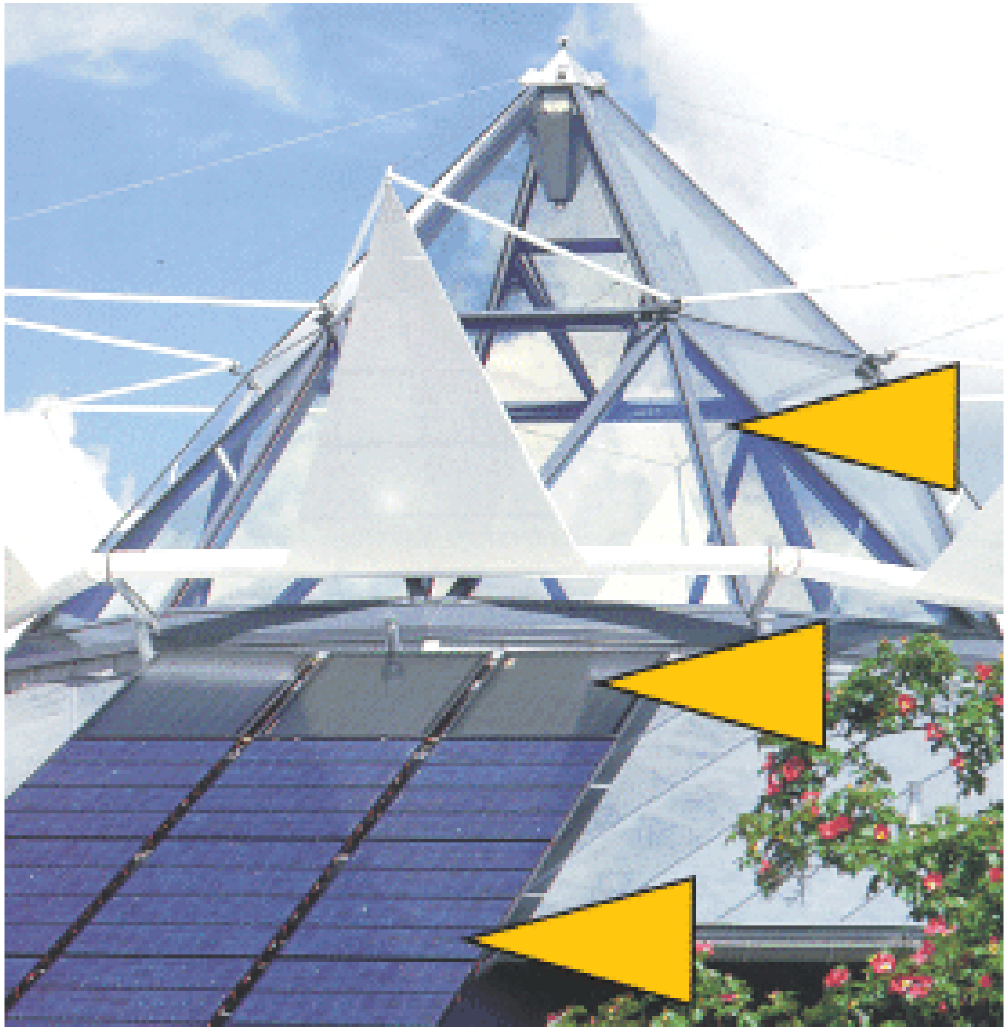
Solar PV systems in Hong Kong Science Park

Renewable energy

- Renewables for buildings
  - Solar energy
    - Passive (low energy architecture)
    - Active (solar thermal)
    - Photovoltaics
  - Other renewables
    - Wind (using buildings to harvest wind energy)
    - Geothermal (e.g. hot springs)
    - Small hydros (e.g. water wheels)
  - Hybrid systems (e.g. PV + wind + diesel)

因地制宜，多能互补。

Integration of solar energy systems in buildings



Passive solar (e.g. skylight)

Active solar (solar hot water)

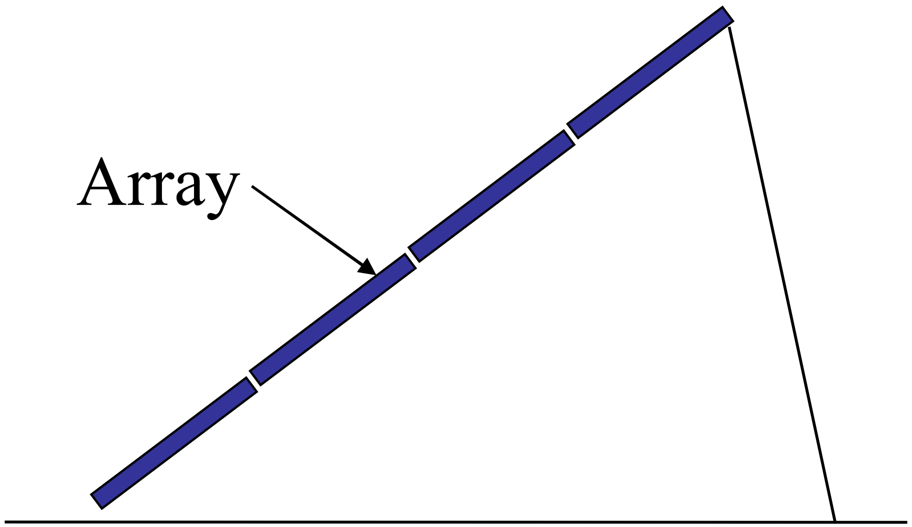
Photovoltaics

Evacuated-tube solar hot water system in a hotel in Lhsa, Tibet (photo taken by Dr Sam C M Hui)

Why Tibet is good for using solar energy?

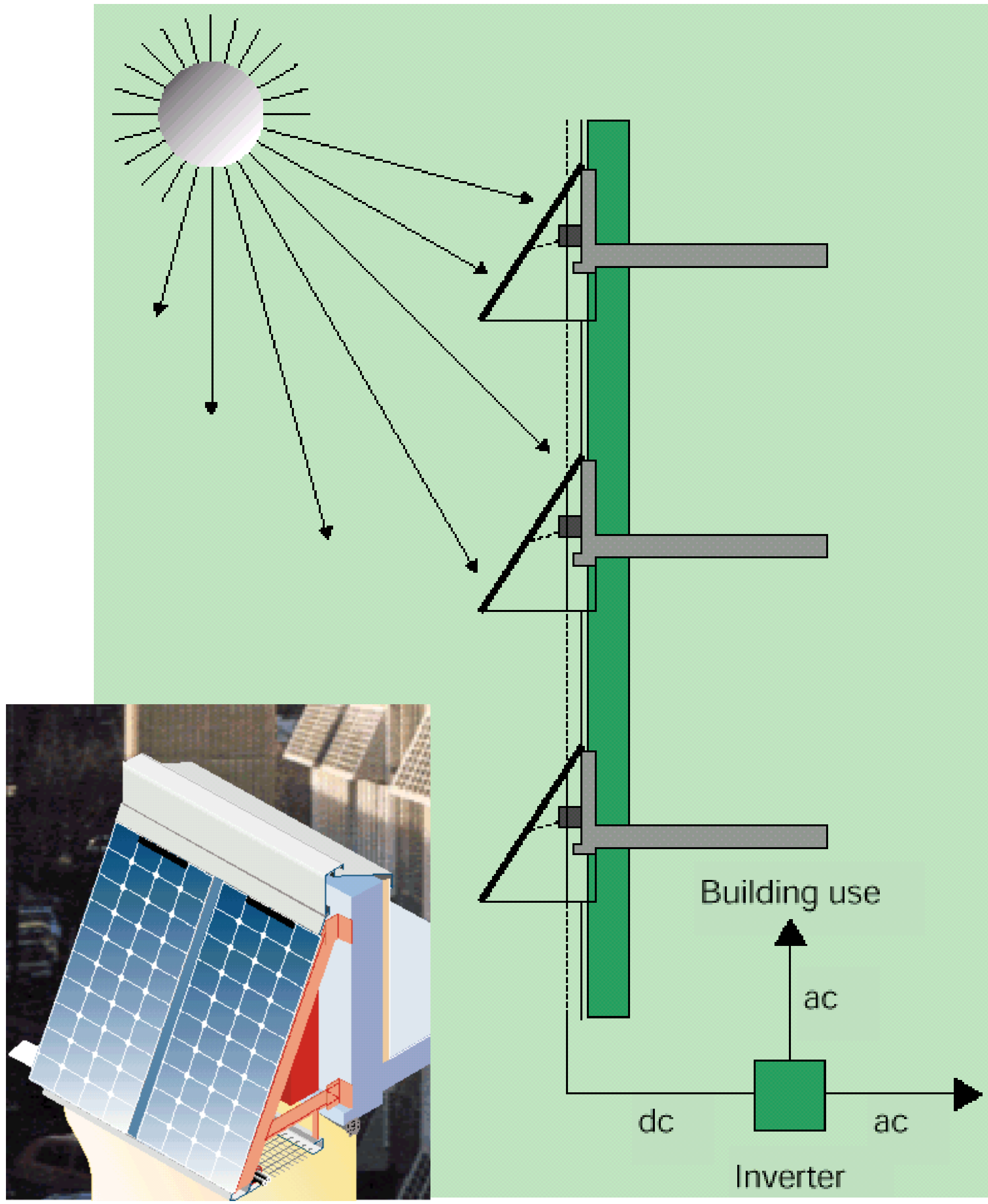
PV installations in buildings

* Locate array in an unshaded area facing the equator



Tilt angle
= latitude (°) + 15°

(a) Roof (horizontal)



(b) Facades (vertical)

Innovative ideas for building integrated renewable energy

Dutch pavilion,
EXPO 2000 Hannover

Project Zed - London

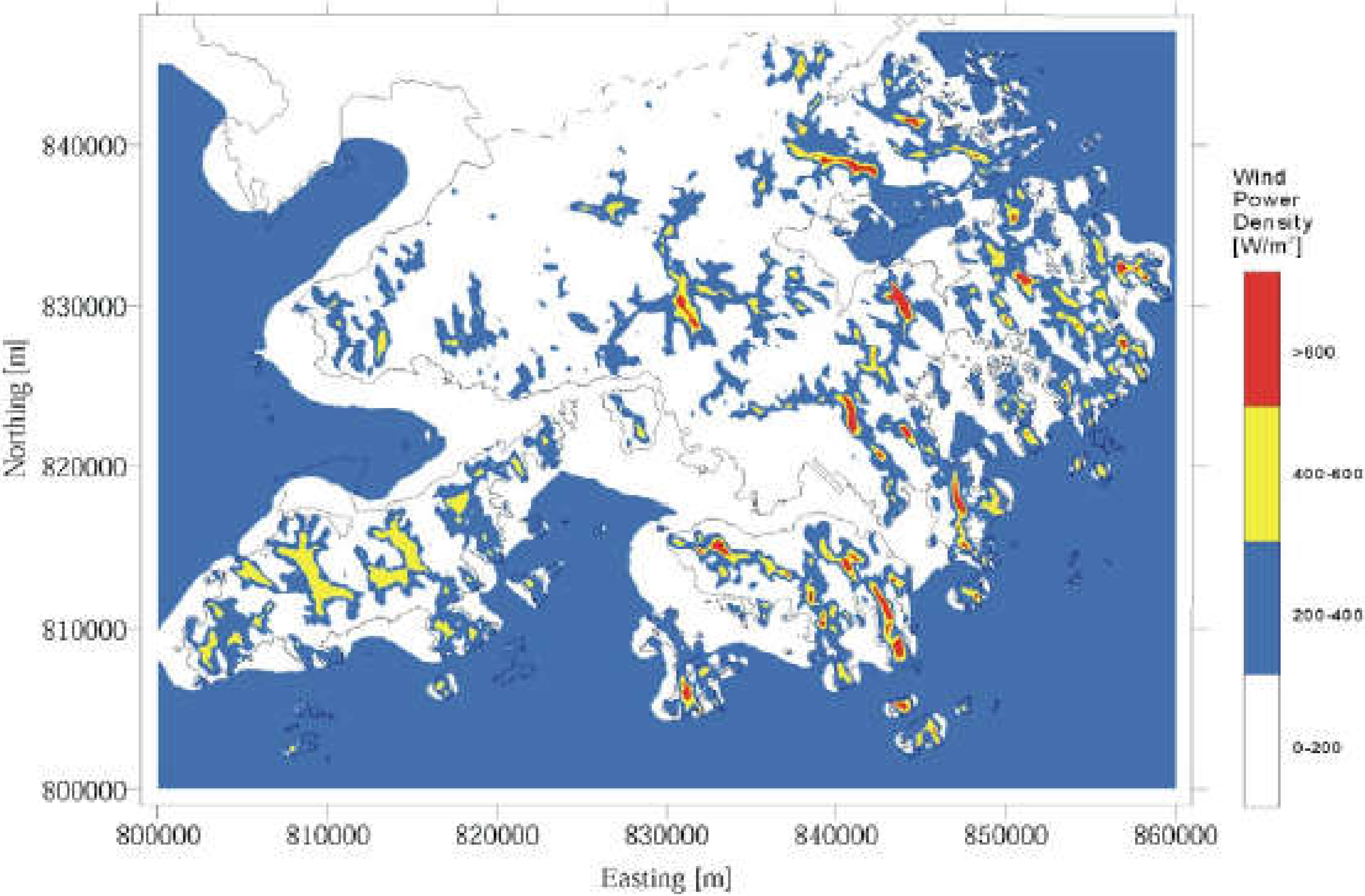
Building integrated wind turbines (World Trade Center in Bahrain)*

* Green Building - Wind Powered, NatGeo World Trade Center Bahrain 1 (14:00)
https://youtu.be/TgBsf3d0u7E

Pearl River Tower, Guangzhou, China

http://en.wikipedia.org/wiki/Pearl_River_Tower
http://www.som.com/projects/pearl_river_tower__sustainable_design

Wind power density over the region of Hong Kong (from EMSD)



Example

Given the following information:

- Wind speed = 6 m/s
- Air density at 30°C = 1.165 kg/m^3
- Rotor radius of a wind turbine facing the wind directly = 25m

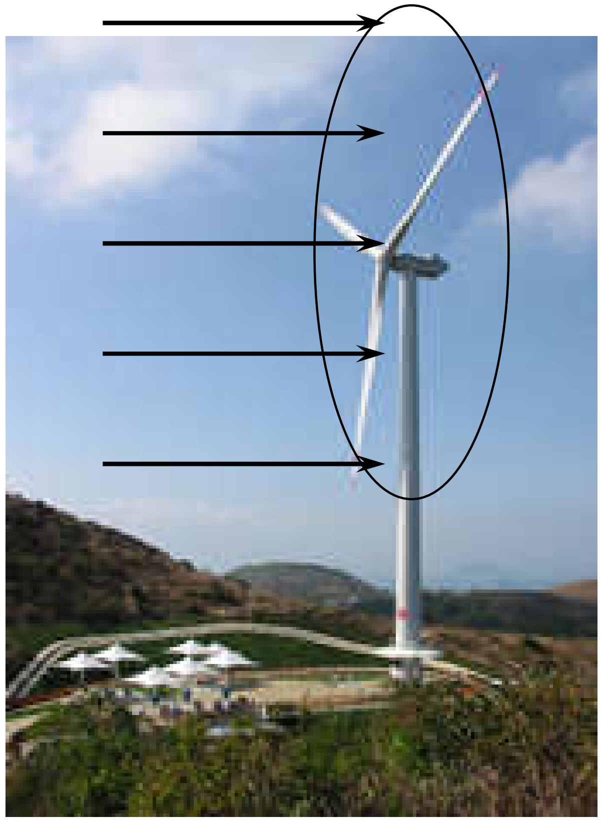
What is the power of incoming wind blowing the wind turbine?

<u>Answer</u>:

$$P = \frac{1}{2}\rho A V^3$$

$$= \frac{1}{2} \times 1.165 \times \left(\pi 25^2\right) \times 6^3$$

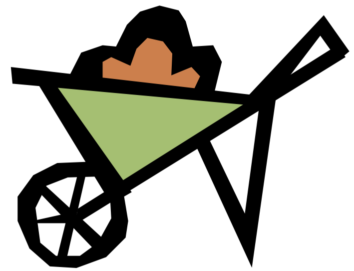
$$= 247{,}047 \text{ W} = 247 \text{ kW}$$



Lamma Wind Power Station 南丫風采發電站, blade diameter of 50m, hub height of 46m and a rated power of 800kW

(Image source: Lamma Wind Power Station https://www.hkelectric.com/en/our-operations/lamma-wind-power-station)

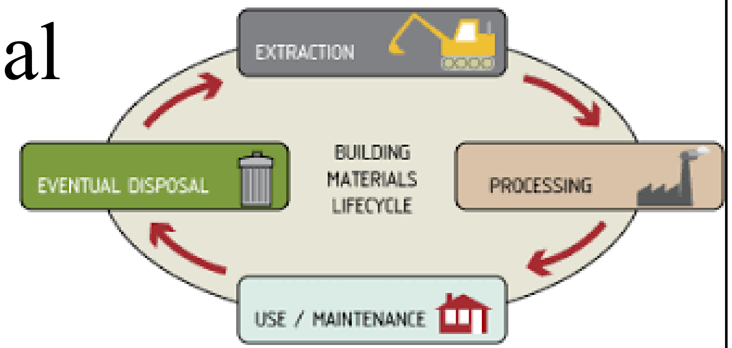
Building materials



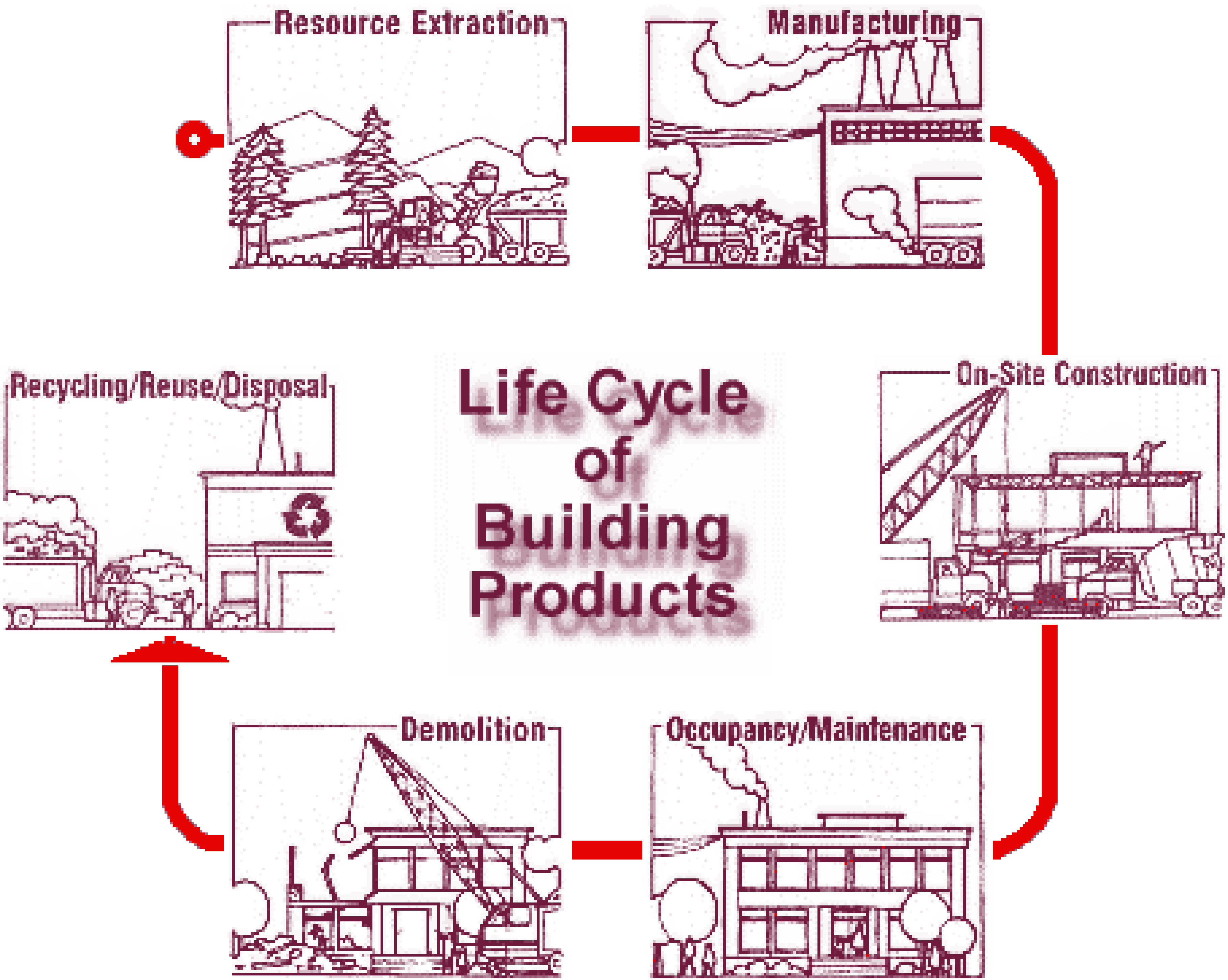
- Environmental impact of building materials
  - Through consumption of resources
  - Through production of resources (by-products, wastes, pollution, recyclables)
- Objectives
  - Make informed environmental choices about building materials and systems
  - Careful design & understanding about materials

Building materials

- What makes a product **green**?
  - Measured by their environmental impact
  - Life cycle of a sustainable material
  - Using local, durable materials
- Embodied energy* 隱含能源
  - 'Lifetime' energy requirement of a material
  - Energy input required to quarry, transport and manufacture the material, plus the energy used in the construction process



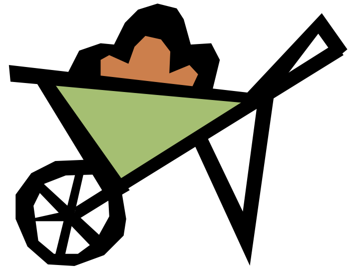
(* http://en.wikipedia.org/wiki/Embodied_energy)


Resource Extraction
Manufacturing
On-Site Construction
Occupancy/Maintenance
Demolition
Recycling/Reuse/Disposal
Life Cycle of Building Products

Estimated embodied energy of insulation materials

Material	Embodied energy (MJ/kg)	Mass per insulating unit (kg)	Embodied energy per insulating unit (MJ)
Cellulose	1.8	0.41	0.7
Fiberglass	28	0.17	5
Mineral wool	15	0.34	5
EPS	75	0.18	13
Polysio	70	0.22	15

Building materials

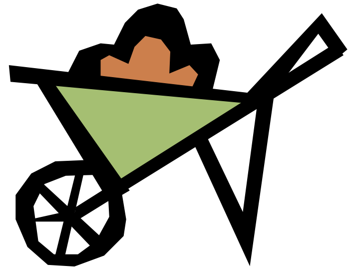


- Specify green materials & products
  - Made from environmentally attractive materials
    - Such as reclaimed, recycled or recyclable products
  - That reduce environmental impacts during construction, renovation, or demolition
  - That reduce environmental impacts of building operation
  - That contribute to a safe, healthy indoor environment
  - That are green because what isn’t there (e.g. CFC)

Green Features

Manufacturing Process (MP)	Building Operations (BO)	Waste Mgmt. (WM)
Waste Reduction (**WR**)	Energy Efficiency (**EE**)	Biodegradable (**B**)
Pollution Prevention (**P2**)	Water Treatment & Conservation (**WTC**)	Recyclable (**R**)
Recycled (**RC**)	Nontoxic (**NT**)	Reusable (**RU**)
Embodied Energy Reduction (**EER**)	Renewable Energy Source (**RES**)	Others (**O**)
Natural Materials (**NM**)	Longer Life (**LL**)	

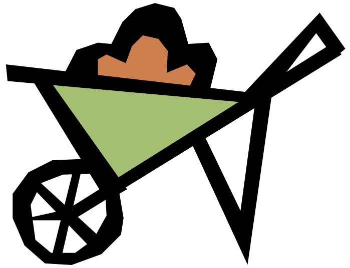
Building materials



- Material conservation
  - Adapt existing buildings to new uses
  - Material conserving design & construction
  - Size buildings & systems properly
  - Incorporate reclaimed or recycled materials
  - Use environment-friendly materials & products
  - Design for deconstruction ("close the loop")

- Life cycle assessment (LCA) is often used to evaluate the environmental impact of building materials and products

Building materials

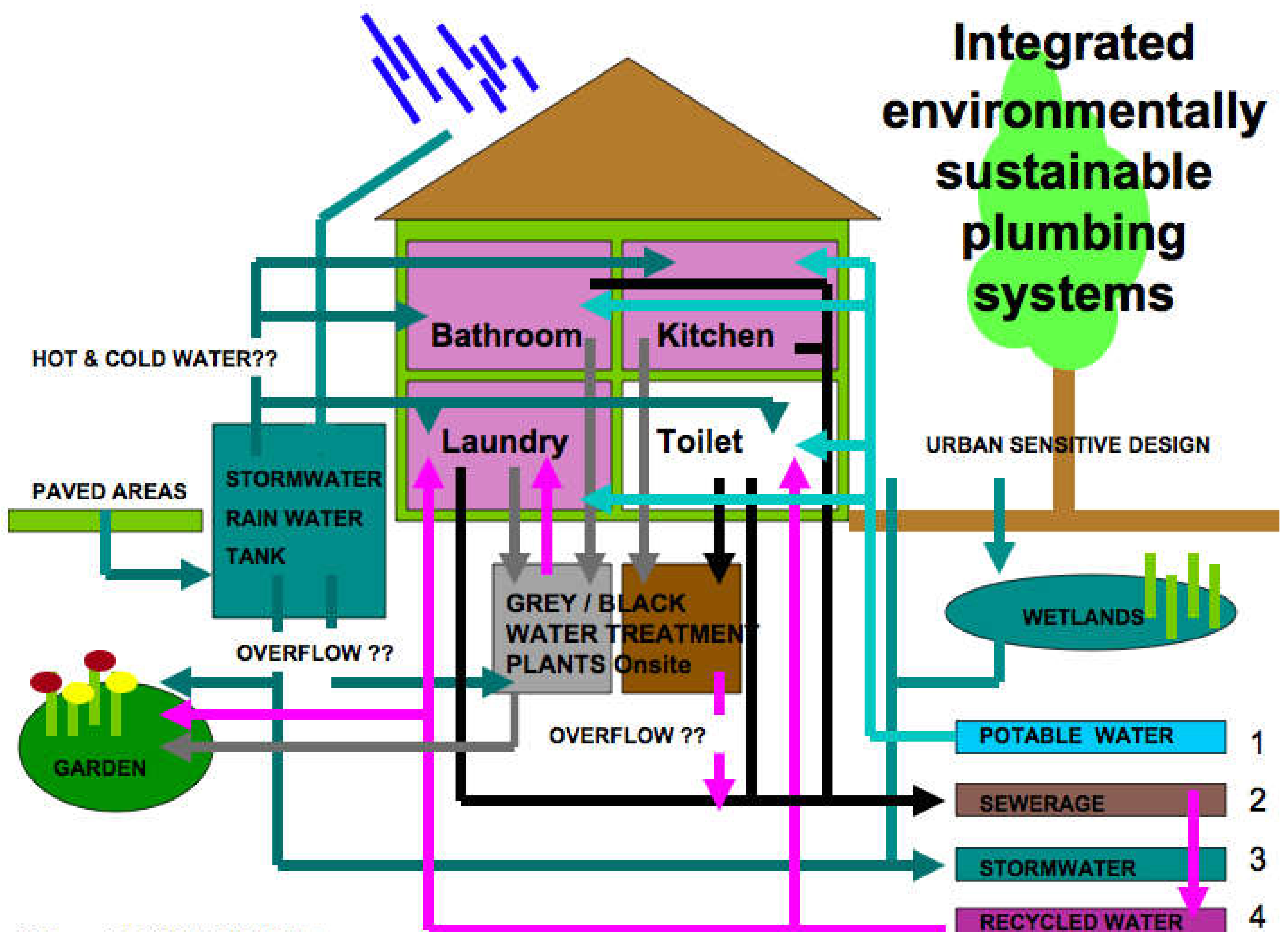


- Waste management strategies
  - Waste prevention & reduction
  - Construction and demolition recycling
  - Architectural reuse
  - Design for material recovery
- Important factors
  - On-site collection & storage space
    - In HK, the space is very limited
  - Sorting & separation (paper, glass, plastic, metal)

Water issues

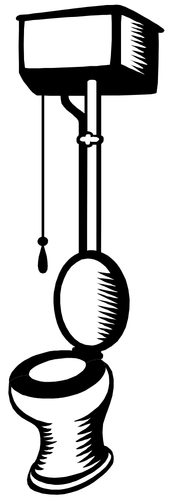
- Stormwater or watershed protection
  - Control rainwater runoff, flooding and erosion
    - Preservation of soils and drainage ways
    - Porous paving materials
    - Drainage of concentrated runoff
  - Avoid pollution and soil disturbance
- Water efficiency and conservation
  - Saving of water and money: water-use charge, sewage treatment costs, energy use, chemical use

>>> Make the best use of water resources.

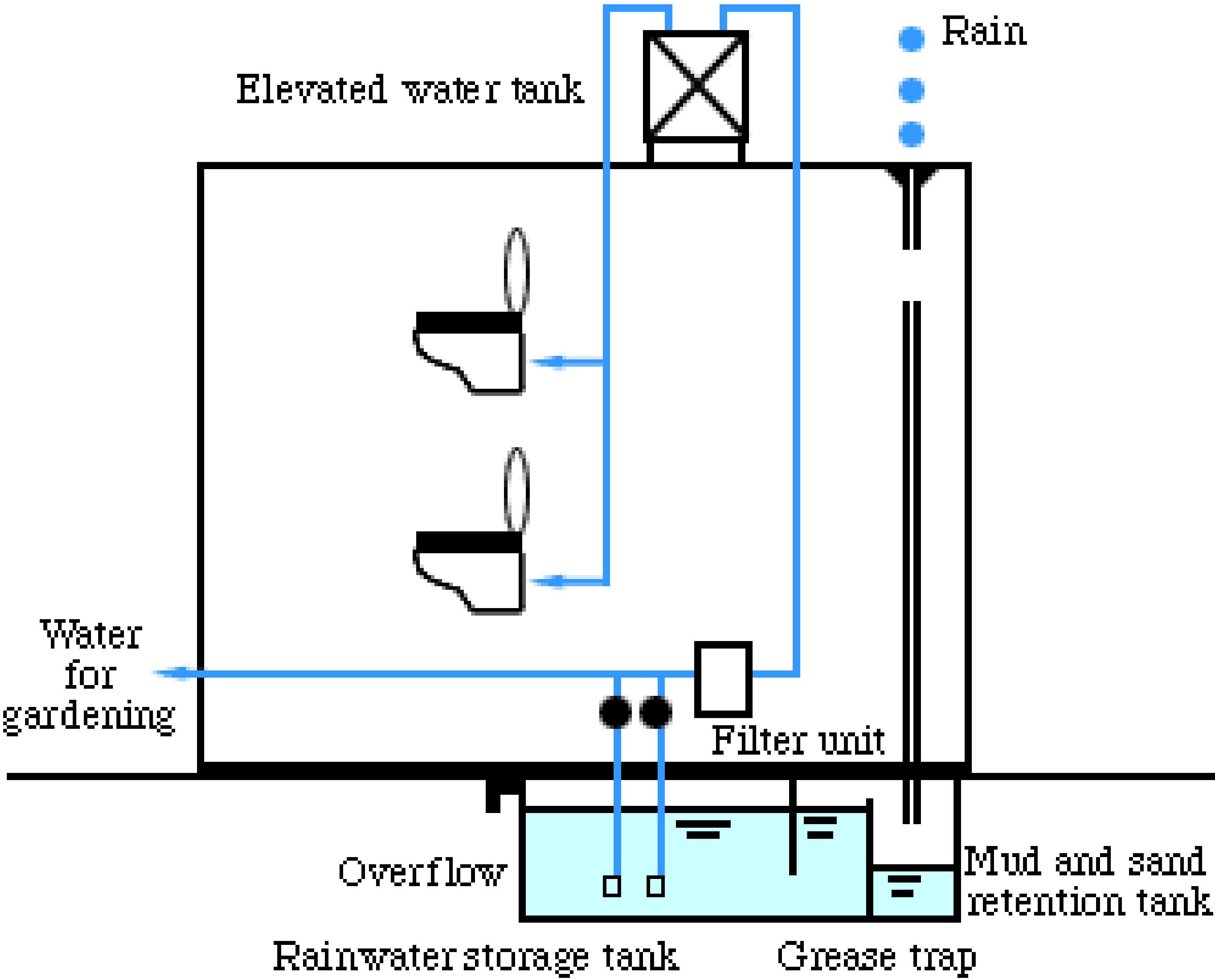

Integrated environmentally sustainable plumbing systems
Bathroom
Kitchen
Laundry
Toilet
HOT & COLD WATER??
STORMWATER
RAIN WATER
TANK
PAVED AREAS
URBAN SENSITIVE DESIGN
GREY / BLACK WATER TREATMENT PLANTS Onsite
WETLANDS
OVERFLOW ??
OVERFLOW ??
GARDEN
POTABLE WATER
1
SEWERAGE
2
STORMWATER
3
RECYCLED WATER
4

Water issues

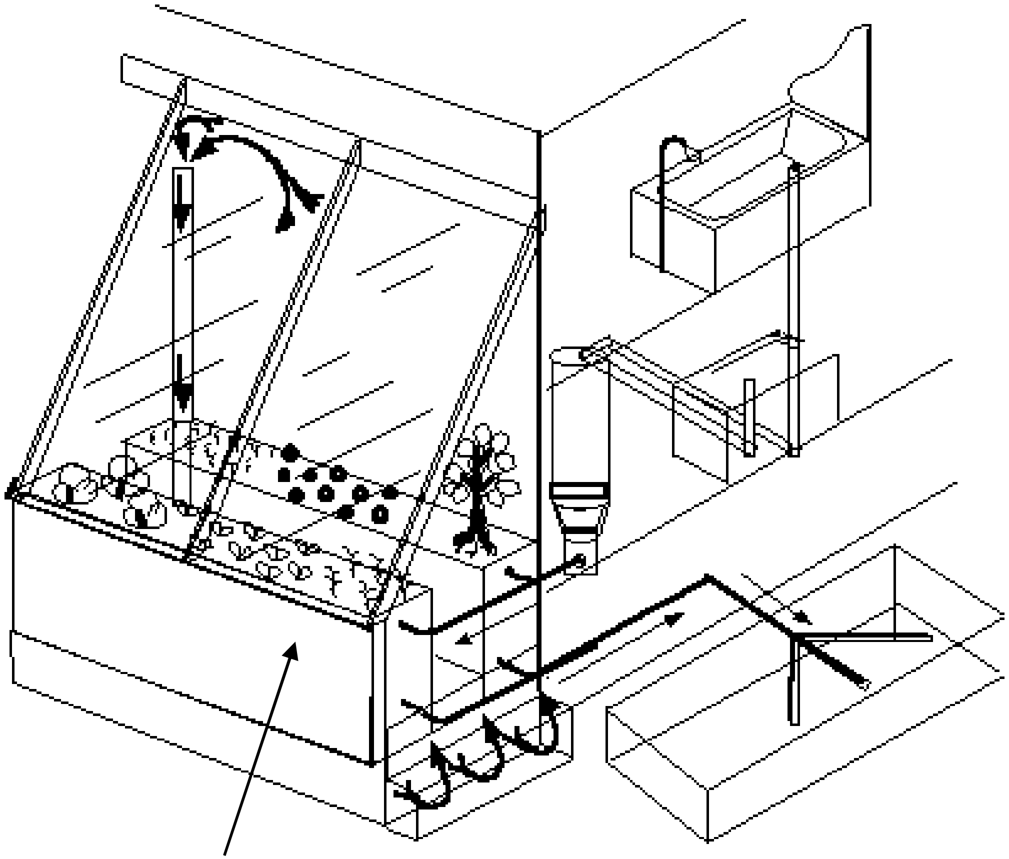
- Design strategy for water efficiency
  - Reduce water consumption
    - Low-flush toilets & showerheads
    - Leak detection & prevention
  - Correct use of appliances (e.g. washing machine)
  - Reuse and recycle water onsite
    - Rainwater collection & recycling
    - Greywater recycling (e.g. for irrigation)
  - No-/Low-water composting toilet



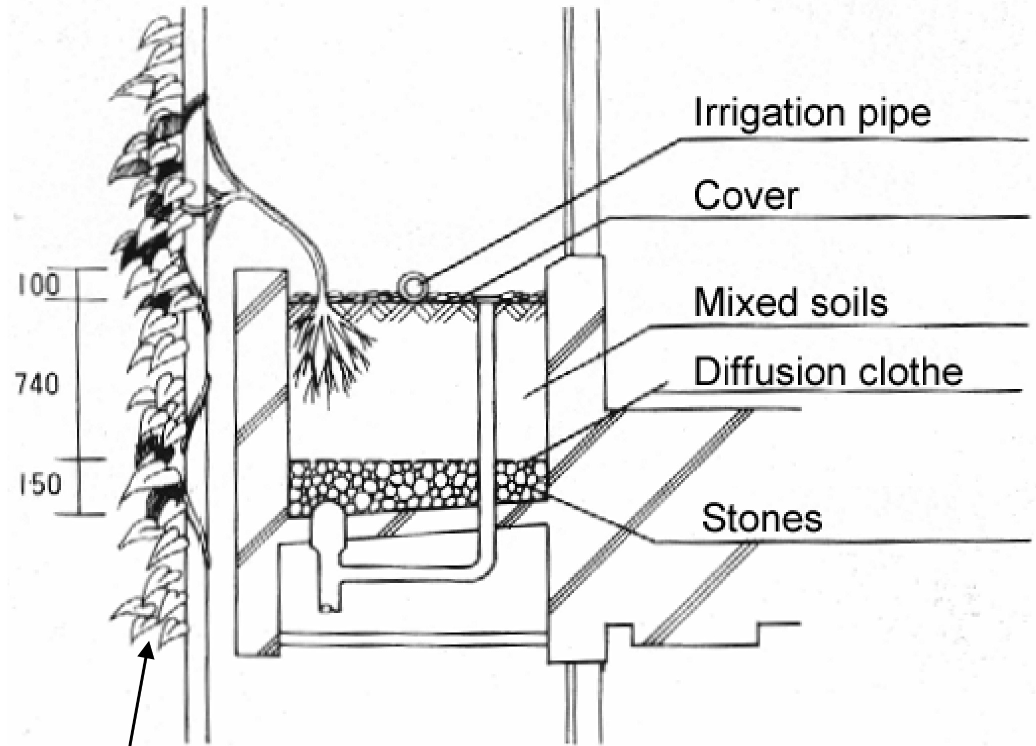
Rainwater recycling system



Using greywater for crops and landscape irrigation

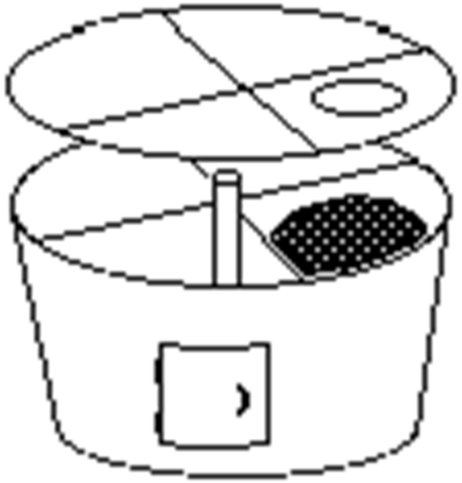


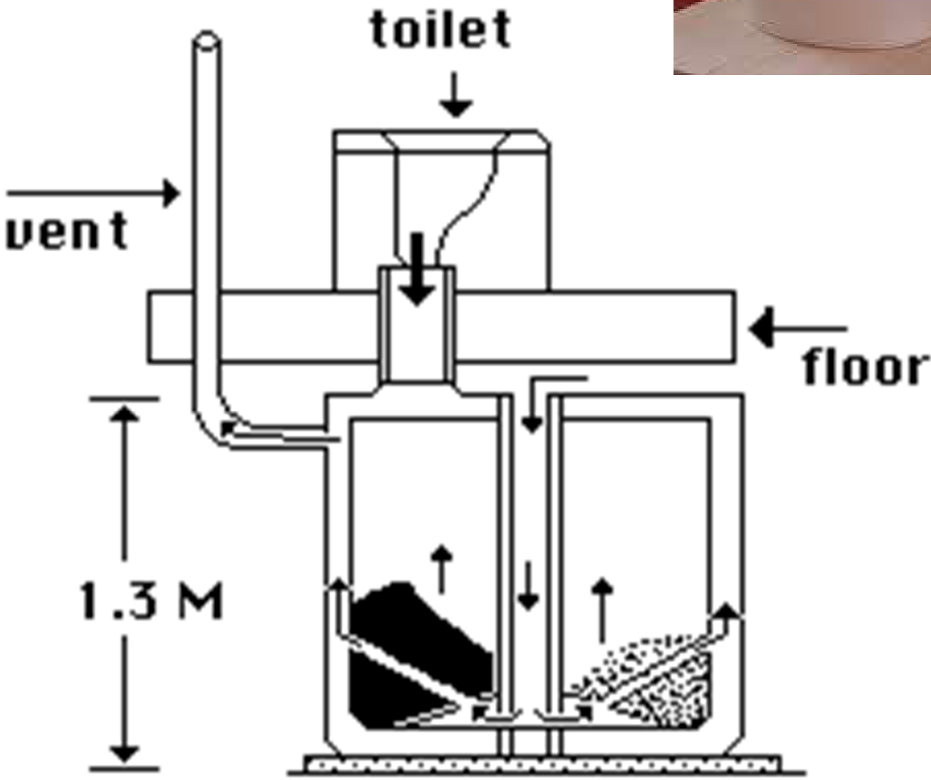
Crops growing
(for food or flowers)

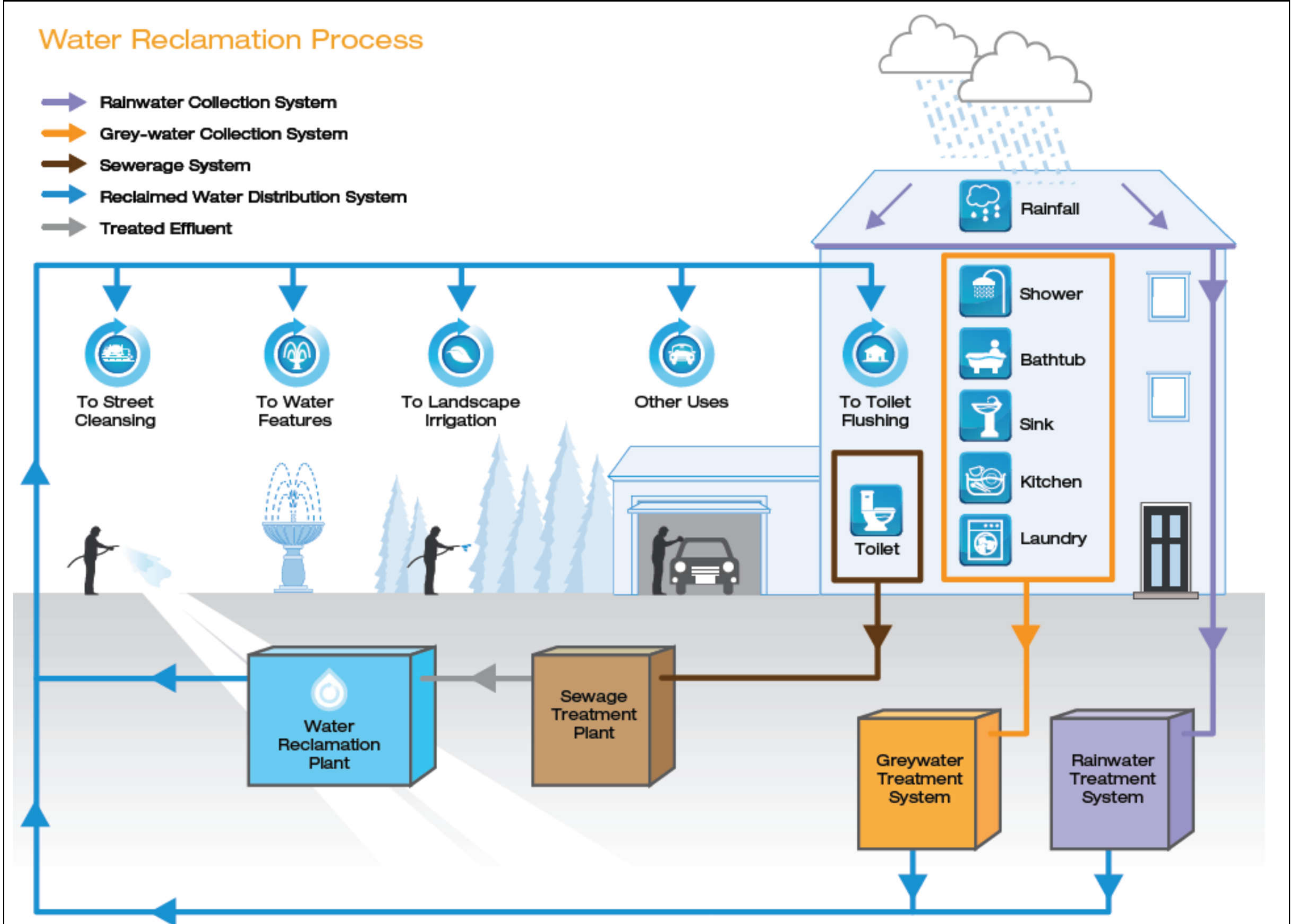


Espalier

Composting toilets 堆肥式廁所

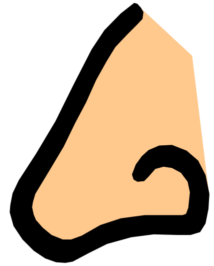






(Source: Water Supplies Department, www.wsd.gov.hk)

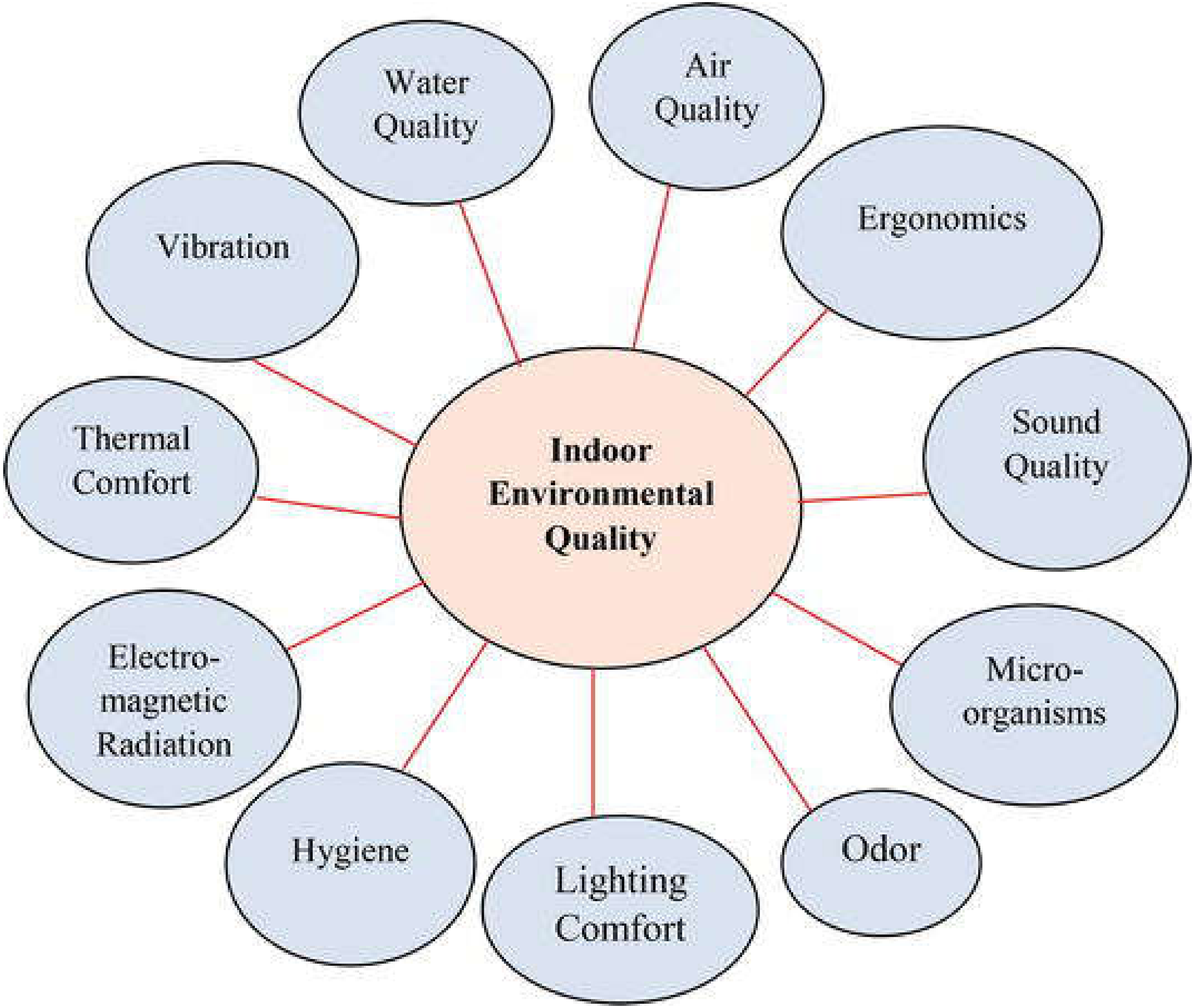
Indoor environment



- Indoor environmental quality (IEQ)
  - Indoor air quality
    - Ensure health & well-being
  - Visual quality
    - Provide daylight & comfortable conditions
  - Acoustic quality
    - Noise control
  - Controllability
    - Allow occupant control over thermal & visual

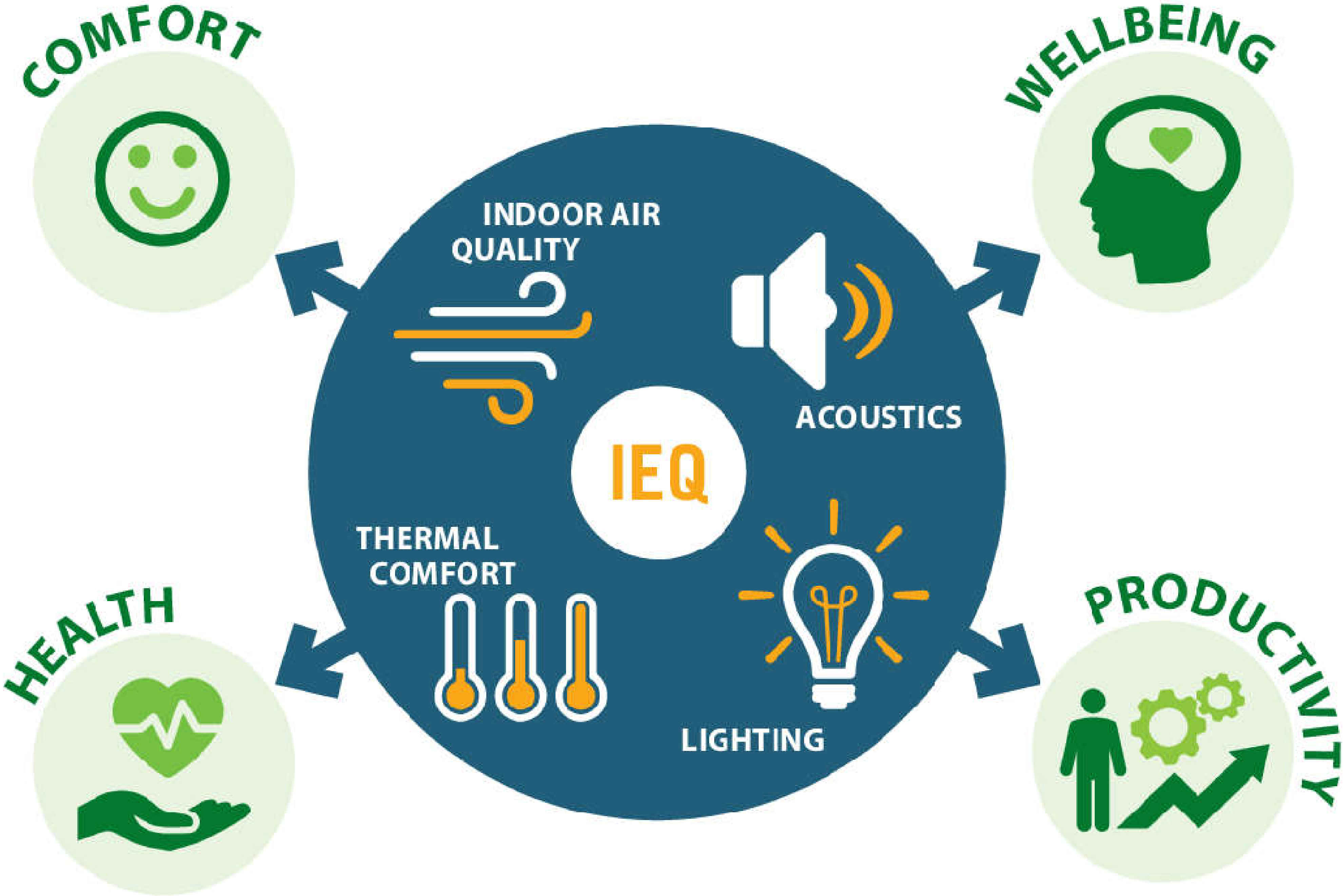
(See also: Indoor environmental quality - Designing Buildings Wiki https://www.designingbuildings.co.uk/wiki/Indoor_environmental_quality)

Components of indoor environmental quality (IEQ)



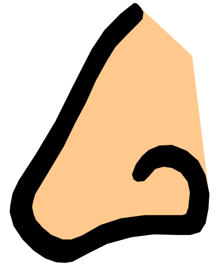
(Source: https://www.intechopen.com/books/indoor-environmental-quality/introductory-chapter-indoor-environmental-quality)

Elements and impact of indoor environmental quality (IEQ)



(Source: http://bpie.eu/wp-content/uploads/2018/10/The-Inner-value-of-a-building-Linking-IEQ-and-energy-performance-in-building-regulation_BPIE.pdf)

Indoor environment

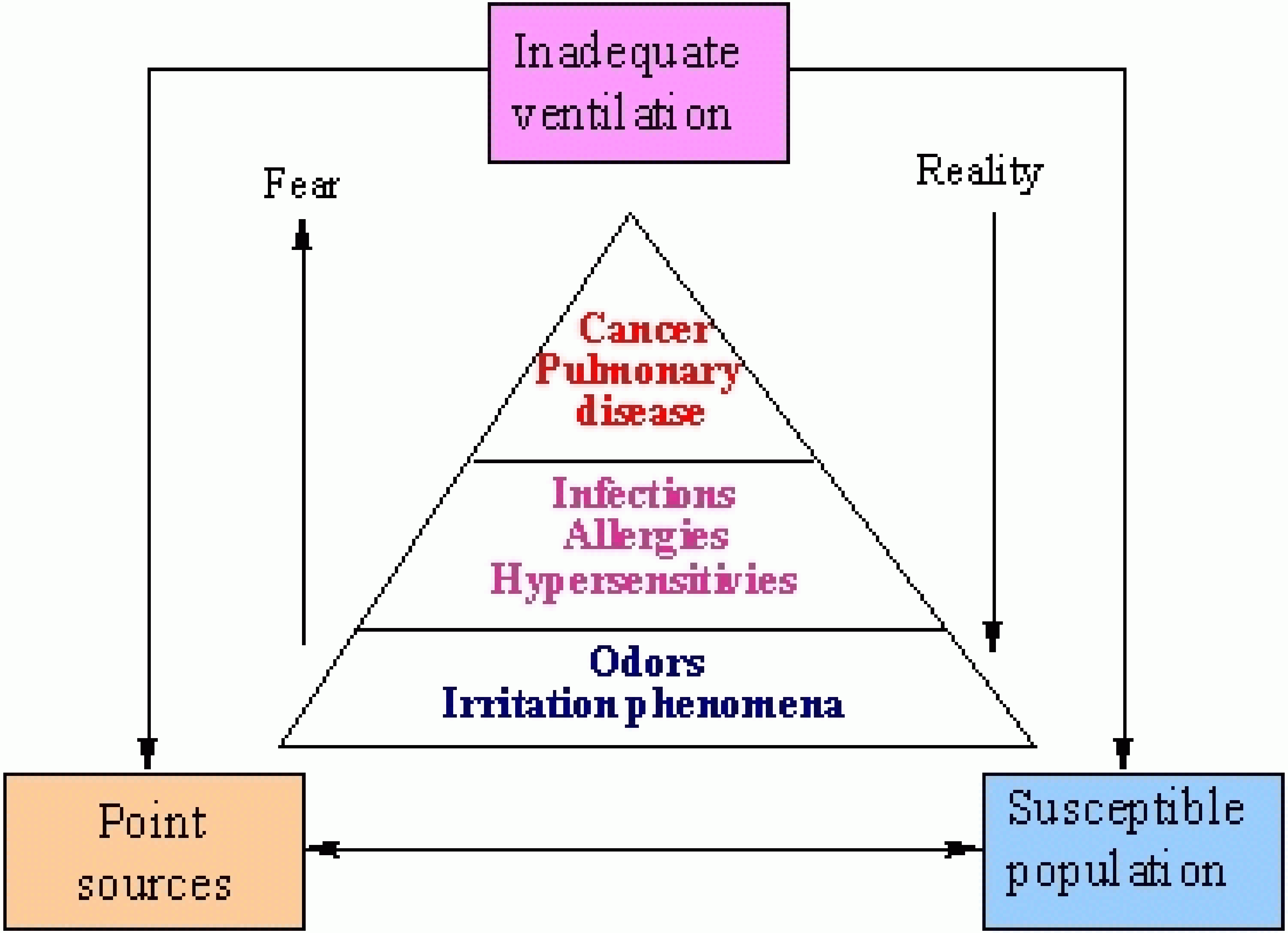


- Indoor air quality (IAQ)
  - People spend most of their time indoors
  - Pollutants may build up in an enclosed space
  - Effects on health and productivity

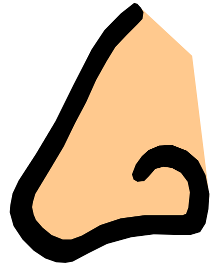
- Control methods
  - Assess materials to avoid health hazards
    - Such as volatile organic compounds (VOC)
  - Ensure good ventilation & building management

Understanding Indoor Air Quality Problems

(Brooks & Davis, 1992)

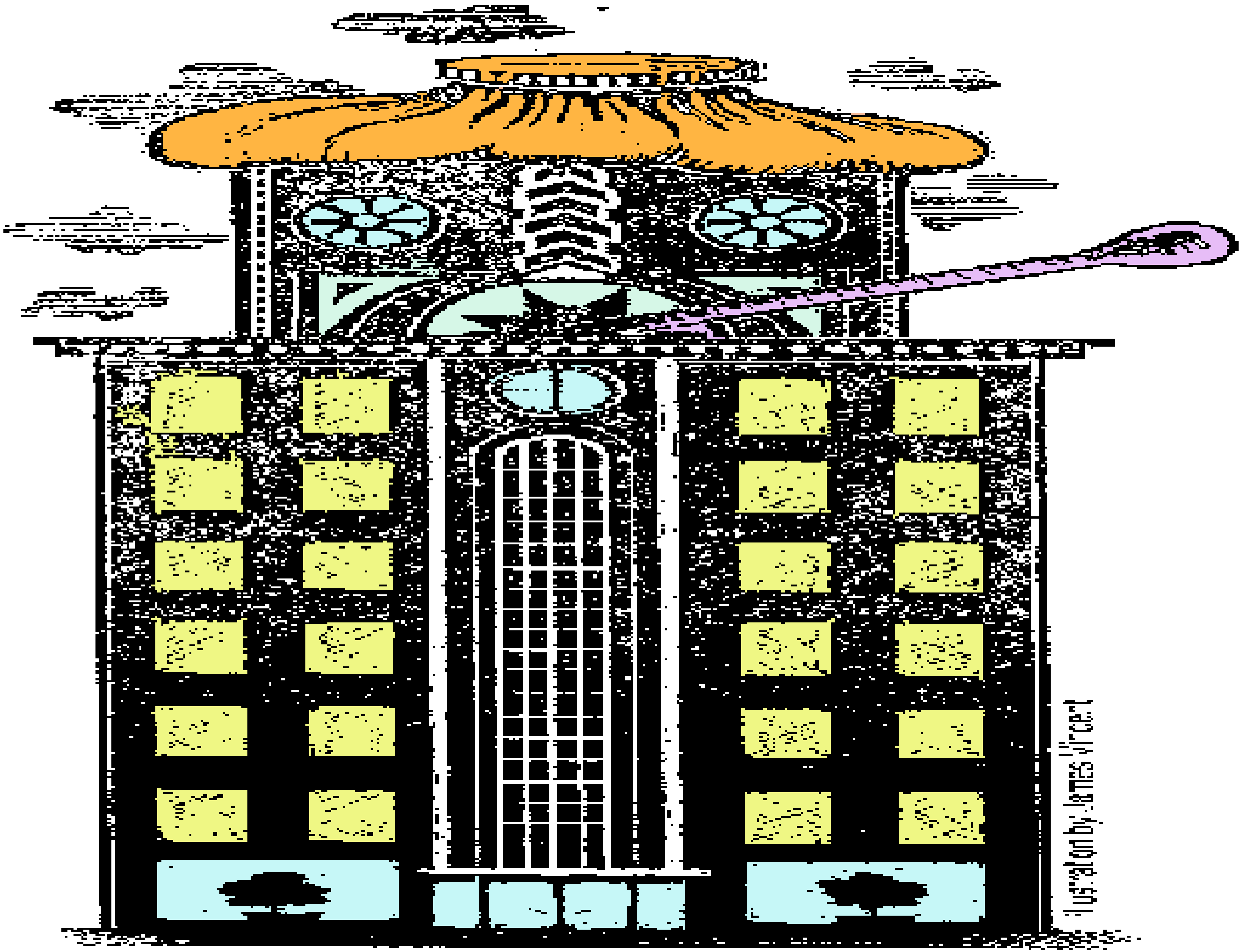


Indoor environment

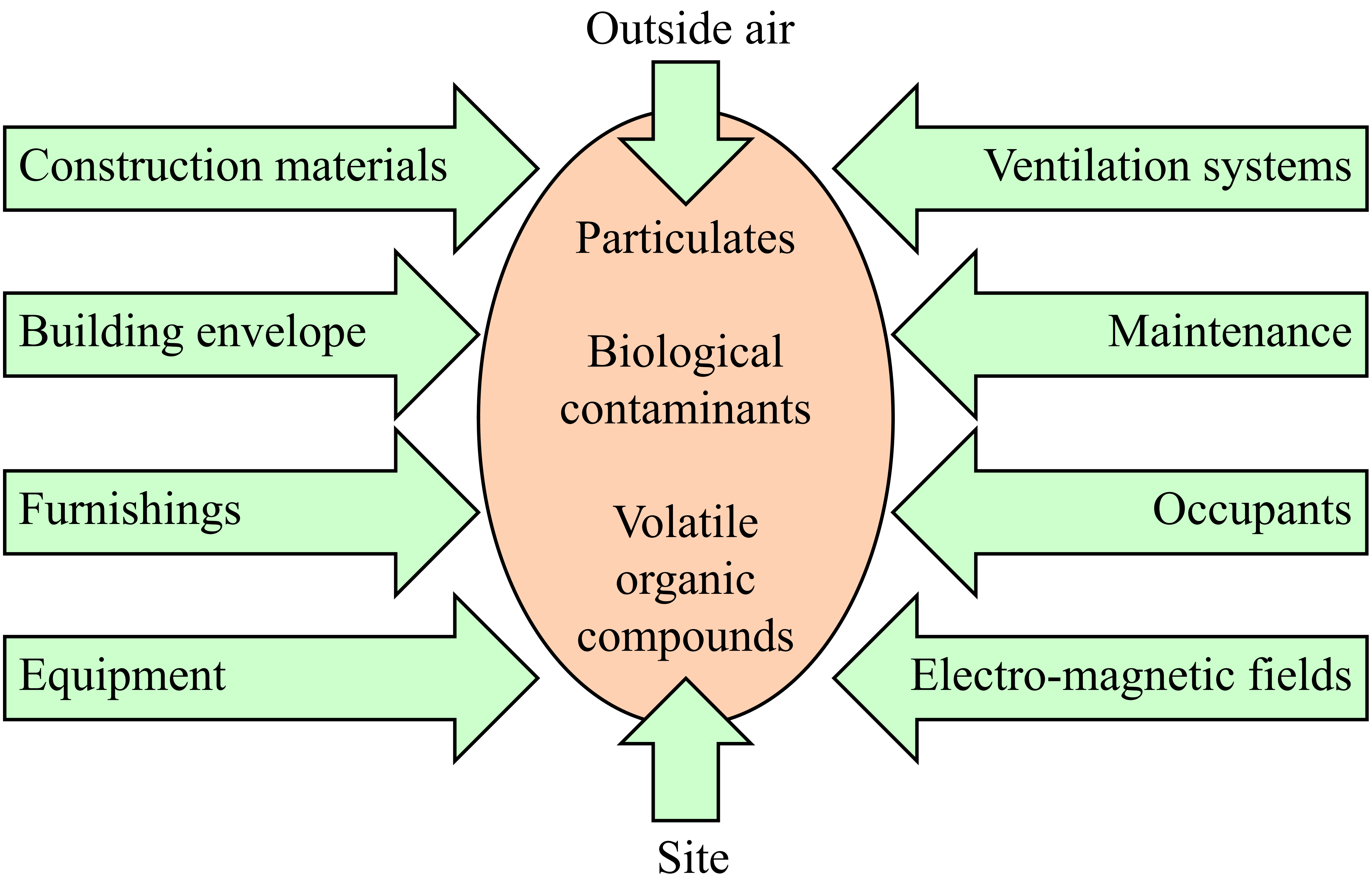


- IAQ problems
  - Not simple, and is constantly changing interaction of complex factors including:
    - Source of pollutants or odours
    - Maintenance and operation of ventilating systems
    - Moisture and humidity
    - Occupant perceptions and susceptibilities (e.g. elderly)
    - Other psychological factors
  - May cause dissatisfaction and complaints, but cannot determine the reasons [Sick Building]

Avoid “sick building syndromes” by maintaining good indoor air quality



Major factors contributing to indoor air quality (IAQ)



(Source: PTI, 1996. *Sustainable Building Technical Manual*)

Four principles of indoor air quality design

1. Source Control

\+

2. Ventilation Control

\+

3. Occupant Activity Control

\+

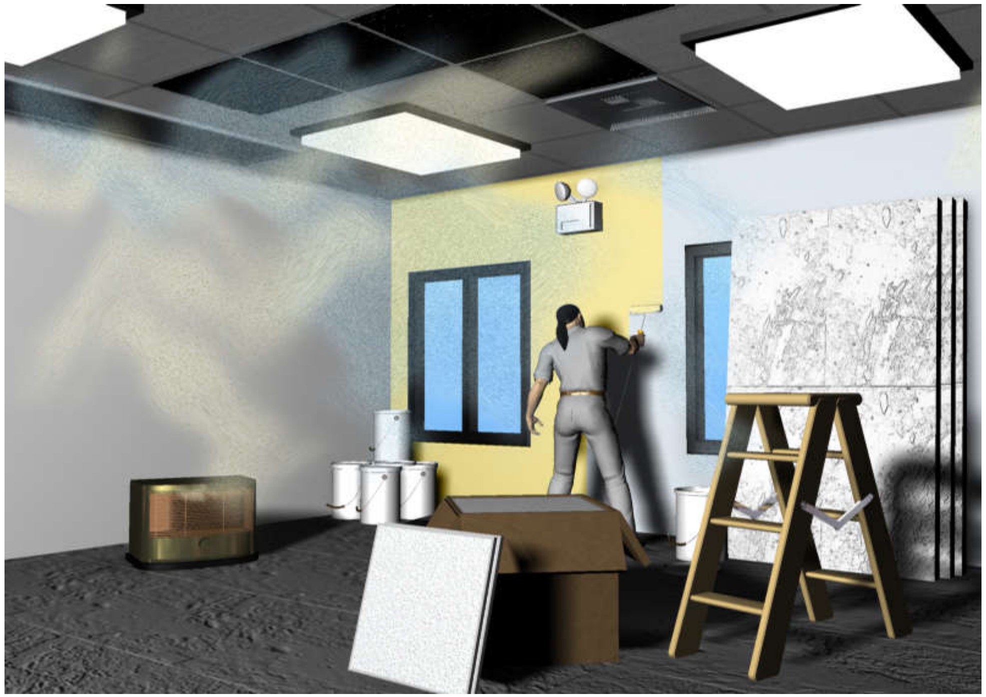
4. Building Maintenance

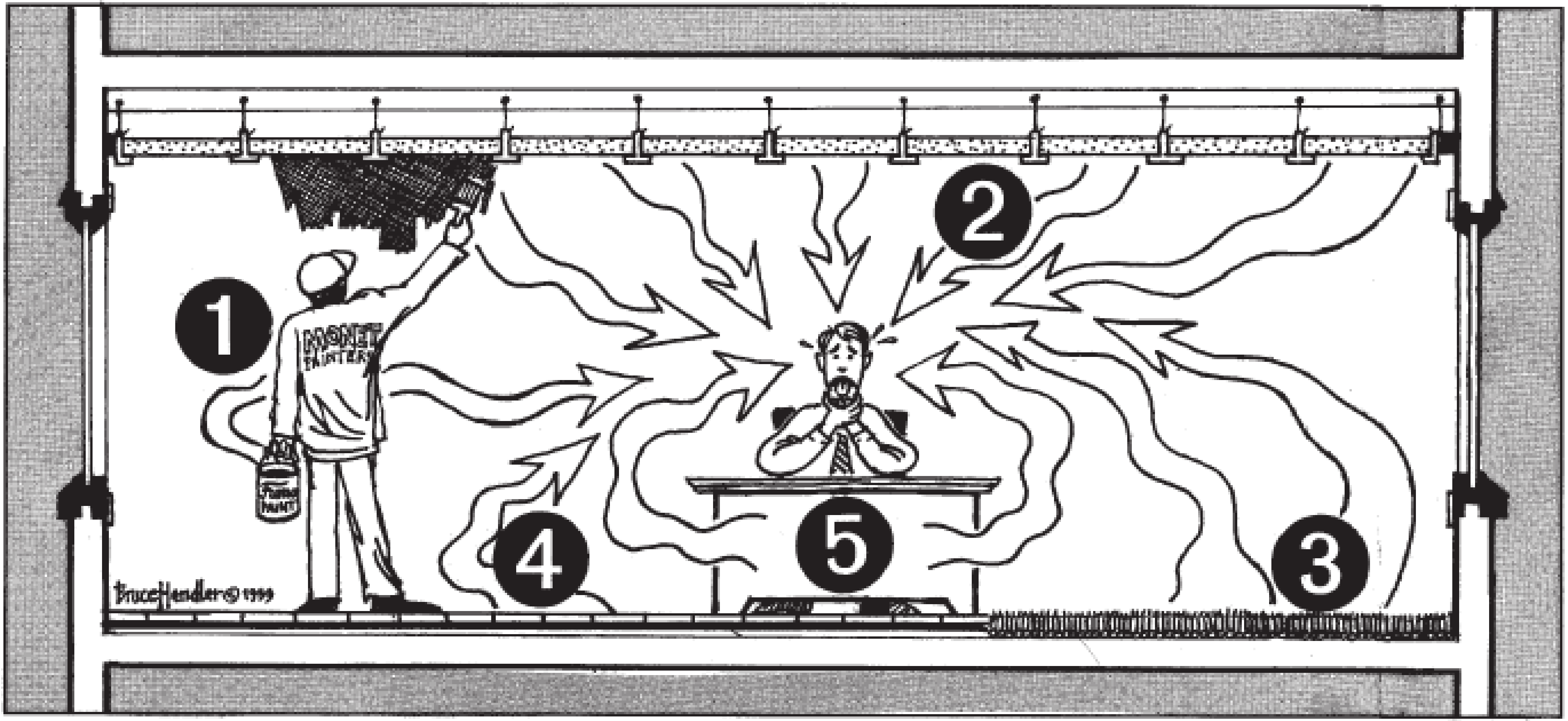
= *Total Indoor Air Quality*

(Source: PTI, 1996. *Sustainable Building Technical Manual*)

Indoor environment

- <u>Source control</u>
  - Site
  - Construction materials
  - Equipment
  - Building contents
  - Human activity
  - Light & noise
  - Furnishings
  - HVAC Systems



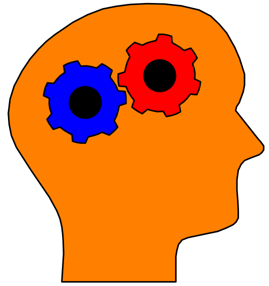


Sources of offgassing in building materials:
1) paints, 2) ceiling tiles, 3) carpeting, 4) VCT floor tiles
5) manufactured wood products

Indoor environment

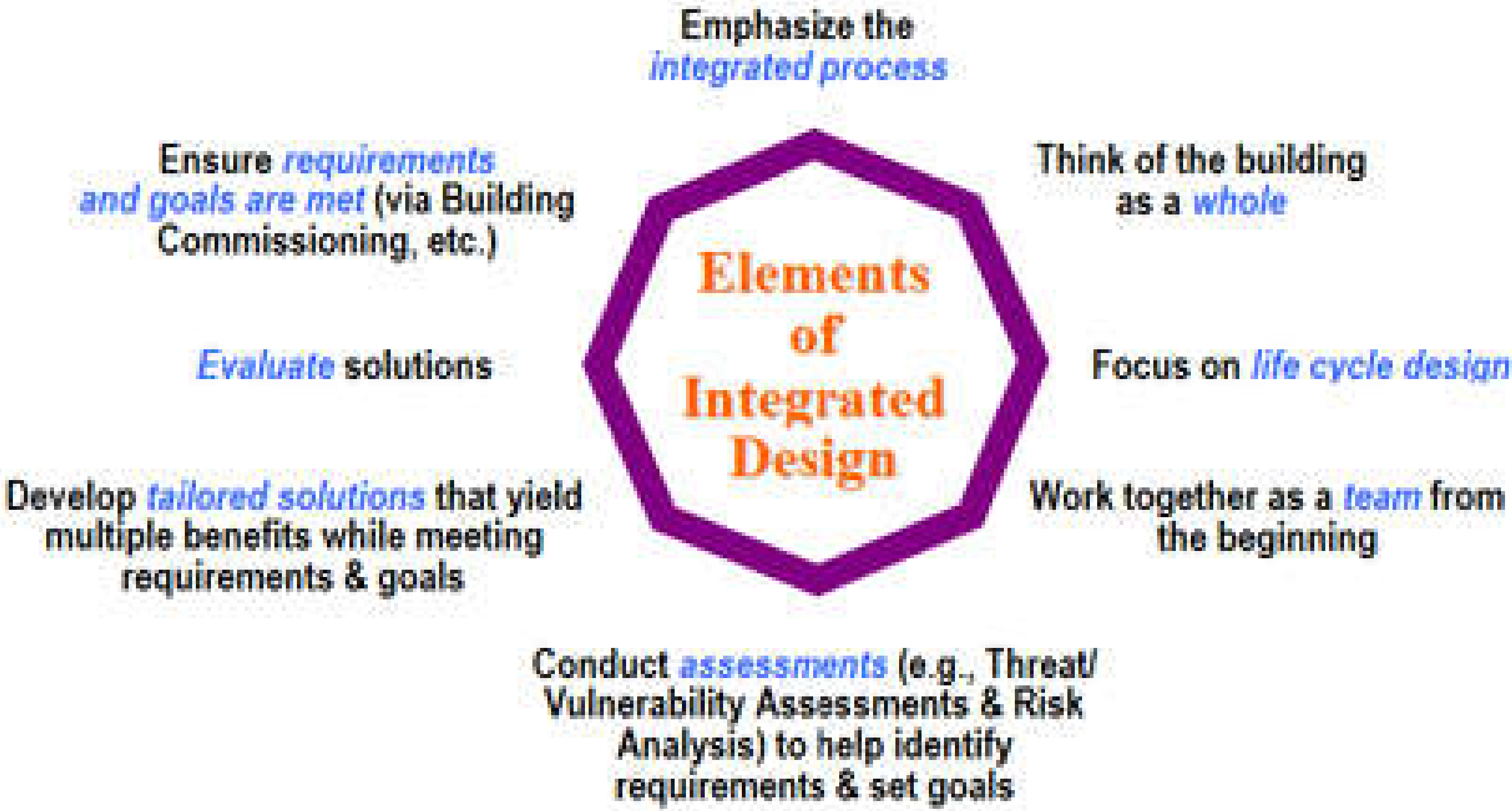
- Ventilation control
  - Air intake location
  - Air exhaust location
  - Air filtration
  - Fibrous insulation
  - Ventilation rates
  - Temperature, humidity
  - Control systems, exhaust systems
  - Building commissioning

Integrated building design



- WBDG - The Whole Building Design Guide
  - Engage the integrated design process http://www.wbdg.org/design/engage_process.php
- Two components of whole building design:
  - Integrated design approach
  - Integrated team process
- A holistic design philosophy
  - Holism + Interconnectedness + Synergy
  - "*The whole is greater than the sum of its parts*"

Elements of integrated design

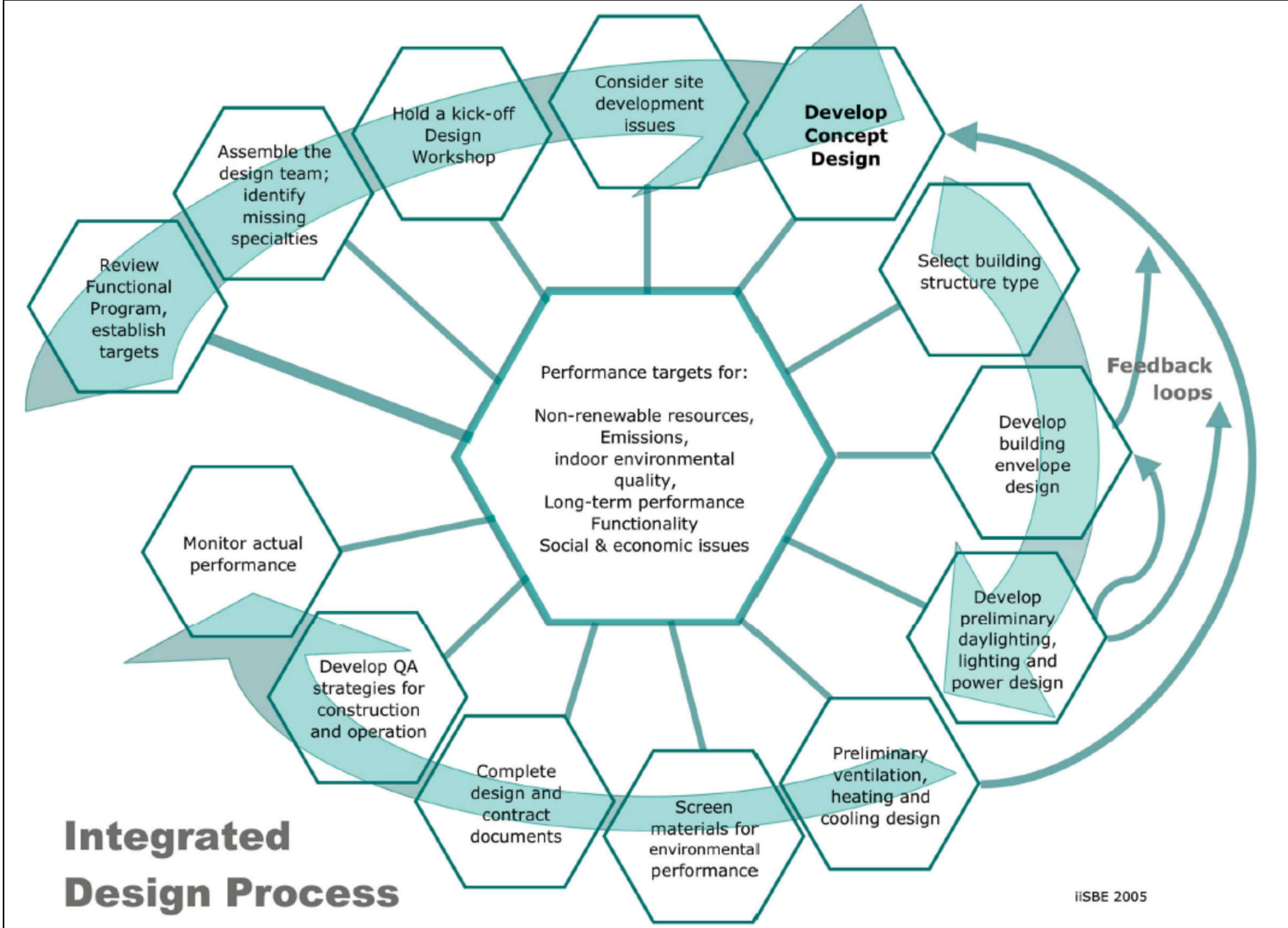


(Source: www.wbdg.org)

Integrated building design

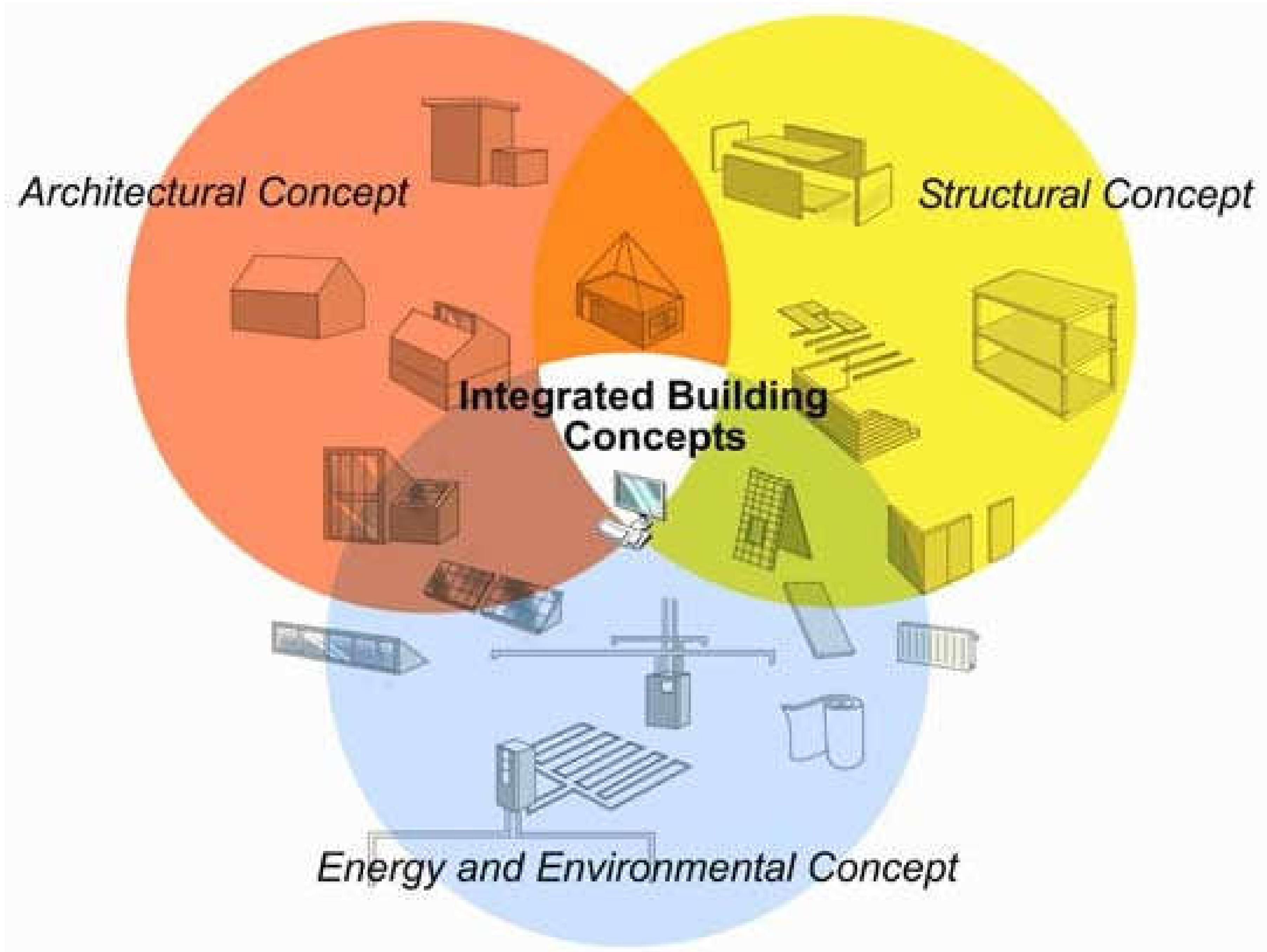
- Typical integrated design process
  - Preparation
  - Design development
  - Contract documents
  - Construction phase
  - Commissioning
  - Post-occupancy evaluation

- Usually more efforts in preparation and pre-design phases



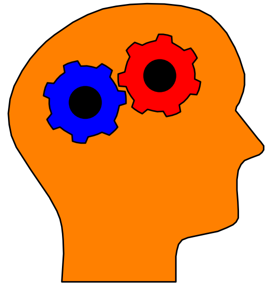
(Source: International Initiative for a Sustainable Built Environment (iiSBE), www.iisbe.org)

Integrated building concepts



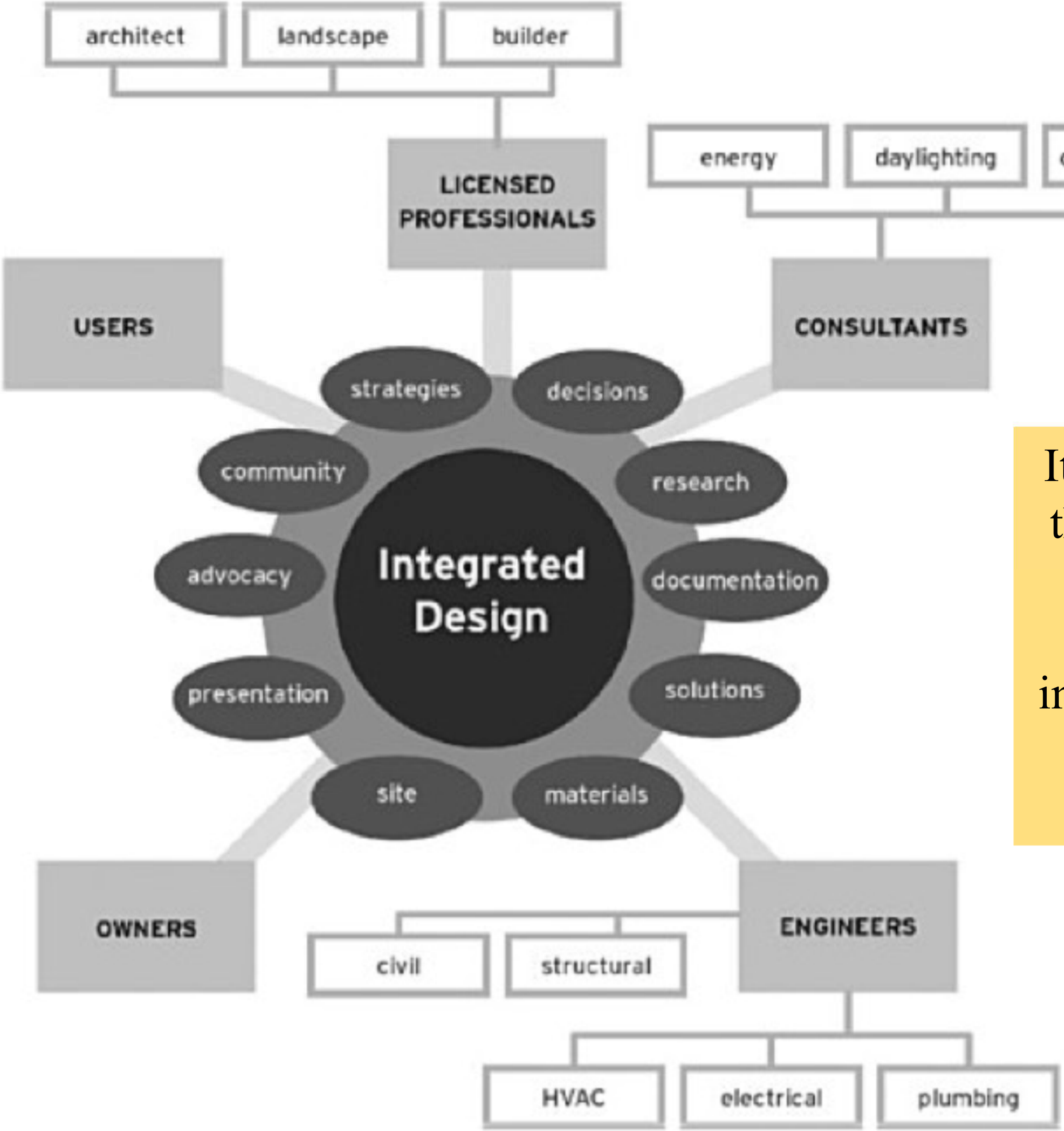
(Source: https://www.researchgate.net/publication/268296386_Integrative_Building_Design_Strategies_for_Integrative_Building_Design)

Integrated building design



- Integrated, multidisciplinary project team
  - Owner's representative
  - Architect
  - Building Services Engineer
  - Civil/Structural Engineer
  - Construction Manager
  - Landscape Architect
  - Specialized Consultants

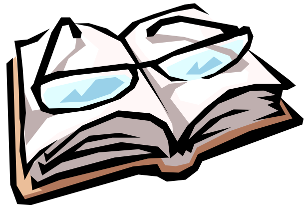
Project stakeholders in collaborative integrated building design process



It requires all players to think holistically about the project with an understanding of the interrelationship of each material, system, and spatial element.

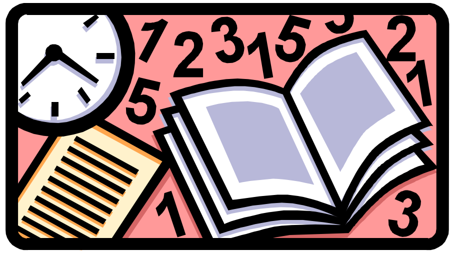
(Source: Keeler M. & Burke B., 2016. *Fundamentals of Integrated Design for Sustainable Building*, 2nd edition, John Wiley & Sons, Hoboken, N.J.)

Further Reading



- Whole Building Design Guide http://www.wbdg.org
  - Sustainable http://www.wbdg.org/design/sustainable.php
- Sustainable Building Technical Manual
  - https://pdhonline.com/courses/g240/Buiilding_%20Systems_%20and_IAQ-Sustainabledesignmanual.pdf
  - Chapter 5: Sustainable Site Design
  - Chapter 6: Water Issues
  - Chapter 13: Indoor Air Quality
- Integrated Design Process Guide
  - http://www.infrastructure.alberta.ca/content/doctype486/production/leed_pd_appendix_7a.pdf

References



- Planning Cities for People: A Guide to Prosperous, Low-Carbon Urbanization https://energyinnovation.org/wp-content/uploads/2014/11/Planning-Cities-for-People.pdf
- Keeler M. & Burke B., 2016. *Fundamentals of Integrated Design for Sustainable Building*, 2nd edition, John Wiley & Sons, Hoboken, N.J. [720.47 K26]
- PTI, 1996. *Sustainable Building Technical Manual: Green Building Design, Construction and Operations*, Public Technology, Inc. (PTI), Washington, D.C. [721.0467 S964][https://pdhonline.com/courses/g240/Buiilding_%20Systems_%20and_IAQ-Sustainabledesignmanual.pdf]