MEBS6020 Sustainable Building Design

http://www.hku.hk/bse/MEBS6020/

Sustainable Building Concepts (II)

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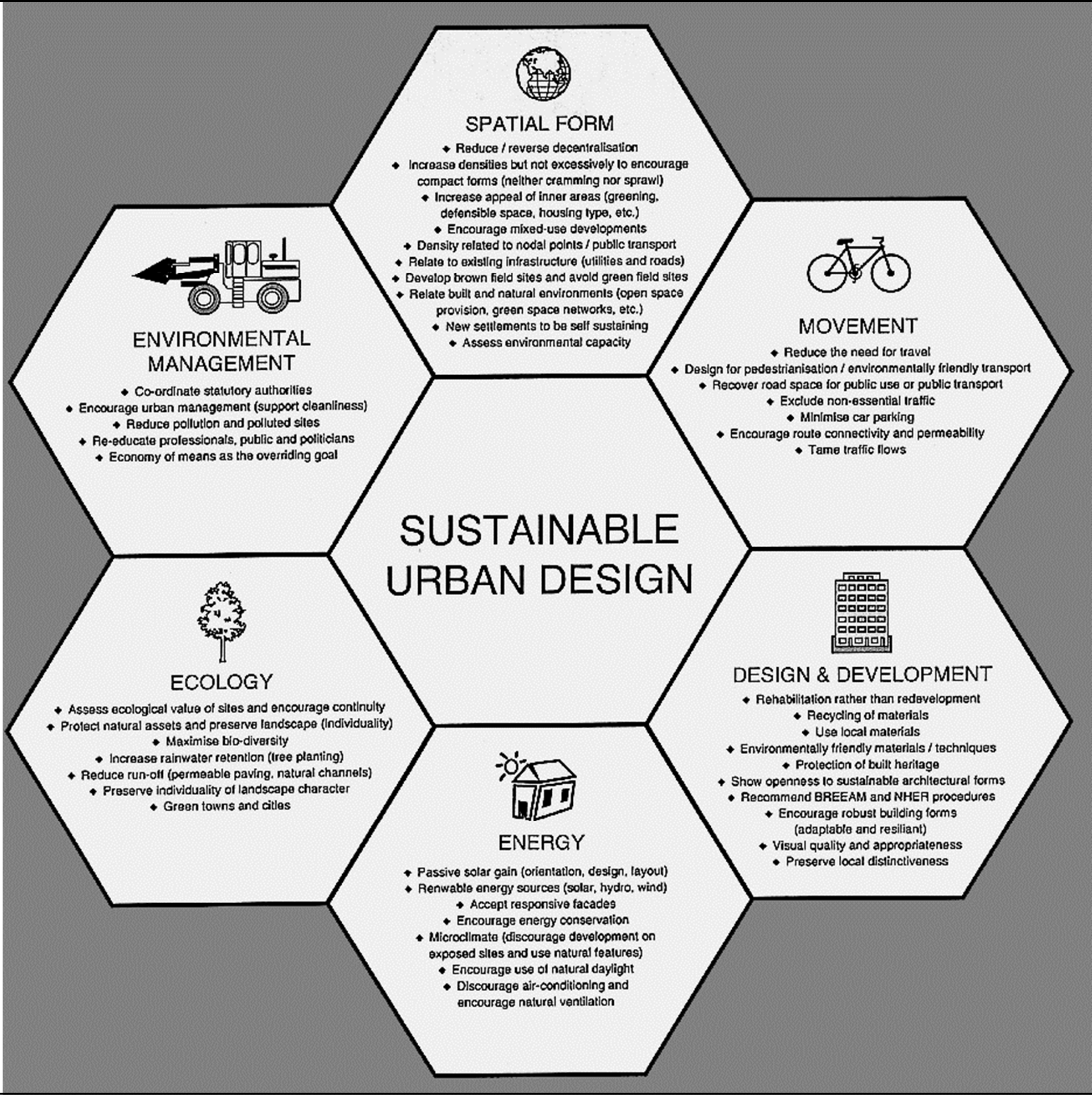
- Urban and site design
- Energy efficiency
- Renewable energy
- Building materials
- Water issues
- Indoor environment
- Integrated building design

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

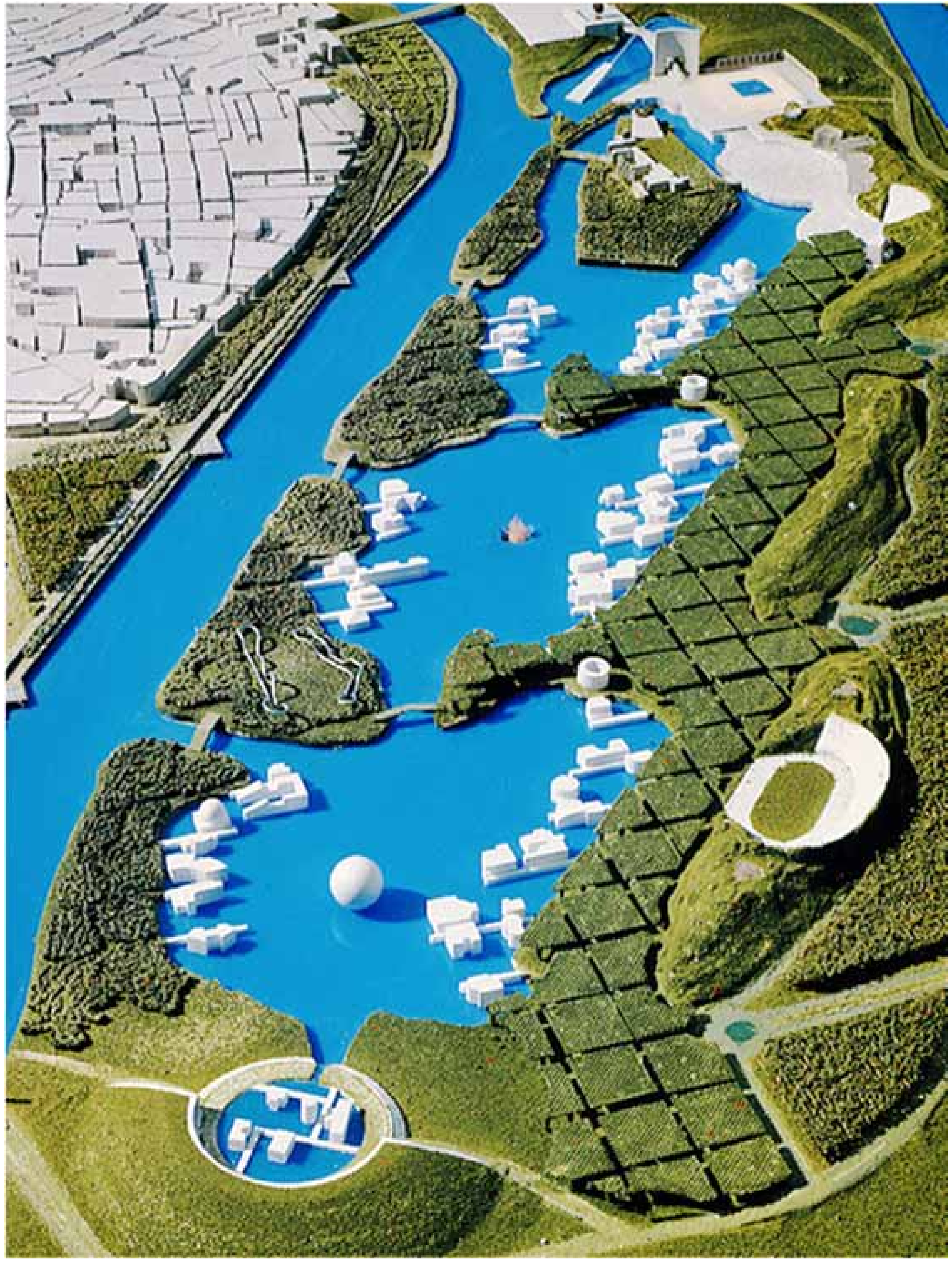
Urban and site design

- 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. An energy strategy
  - 7. Water strategy



Master plan of EXPO’92, Seville, Spain (designed by Emilio Ambasz)

- The pavilions were removed after the EXPO leaving only the garden park to the city and buildings for the local university.

Further info: http://en.wikipedia.org/wiki/Seville_Expo_%2792

Urban and site design

- Design issues:
  - Site selection (e.g. prefer brownfield site*)
  - 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.]

Urban and site design

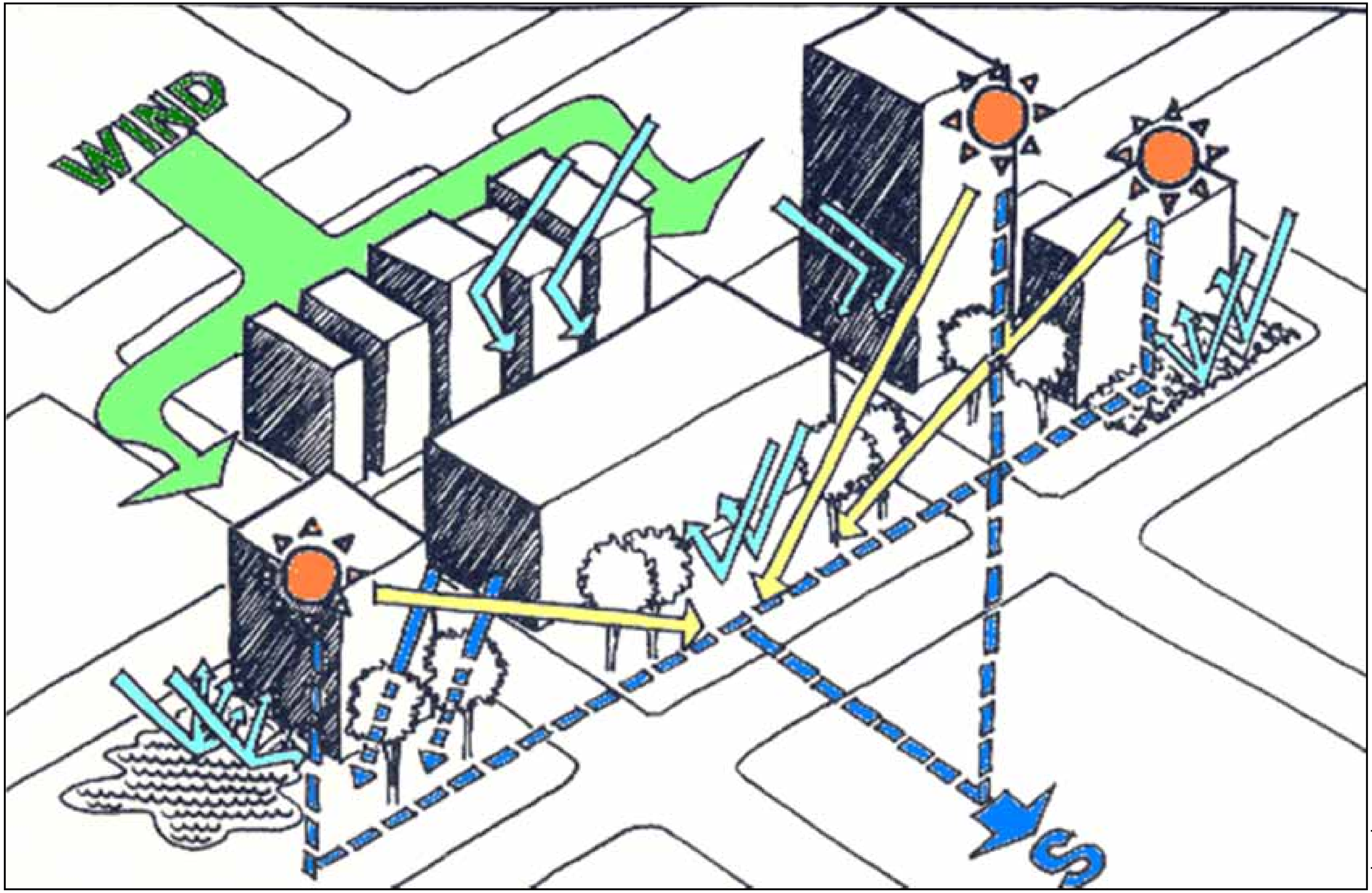
- Design strategies
  - Integrate design with public transportation
    - Quite successful in Hong Kong
  - Promote mixed use development
    - Such as residential + commercial
  - Respect topographical contours (land forms)
  - Preserve local wildlife and vegetation
  - Make use of landscaping and planting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

風

Wind

光

Light



水

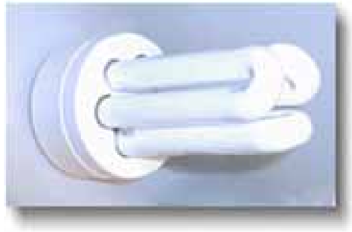
Water

物

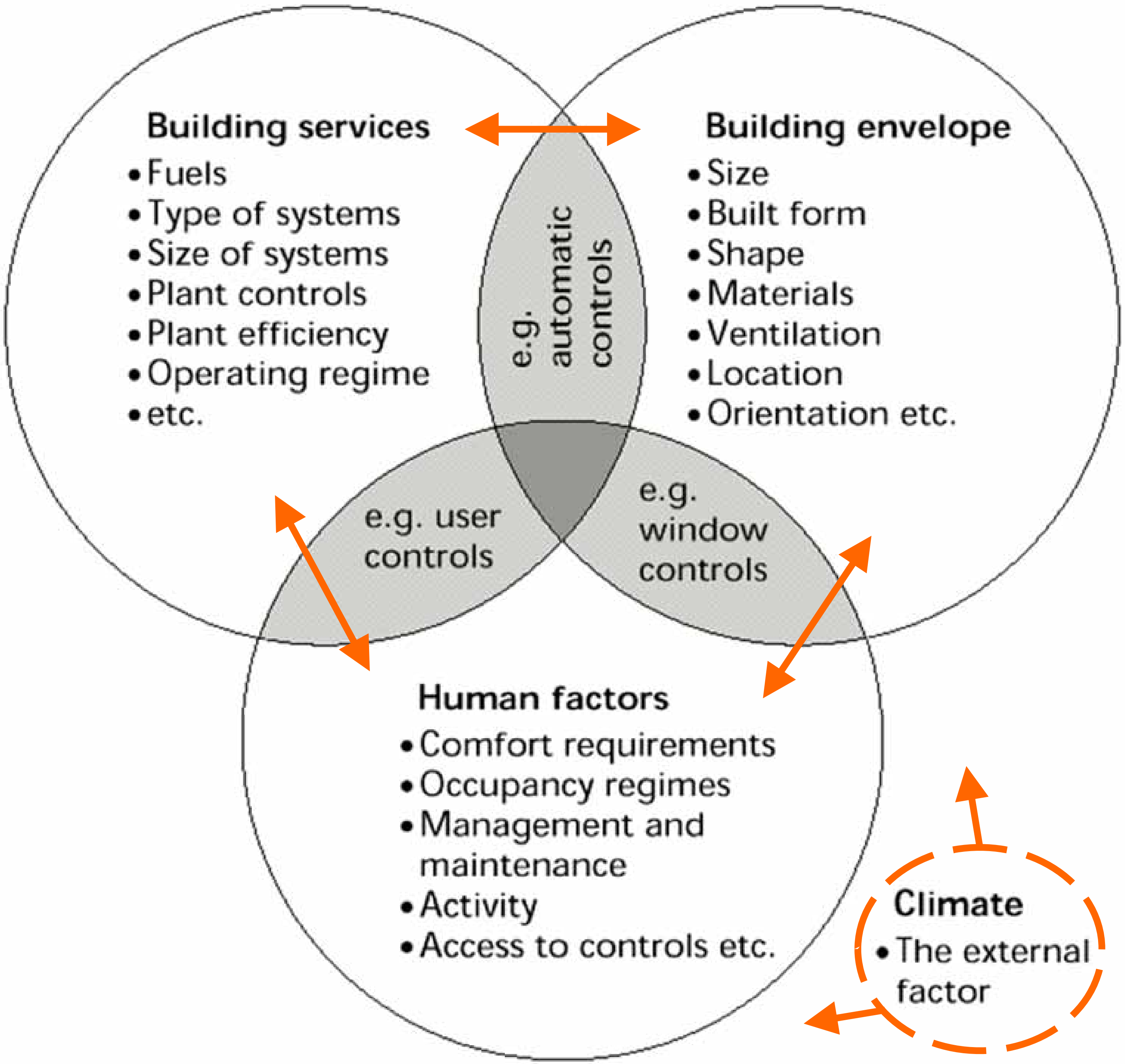
Matter

Site analysis and understanding of the environmental factors is important

Energy efficiency



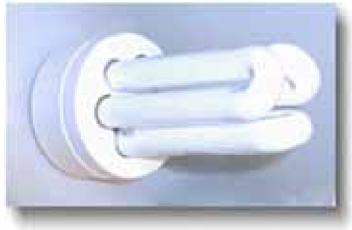
- The need for **energy efficiency**
  - Economics
    - Energy costs and operating costs
  - Environment
    - Climate change, global warming, air pollution
  - Energy security
    - Energy supply (political and economic reasons)
  - Resources depletion
    - Oil, gas and coal will be used up



Key factors influencing energy consumption

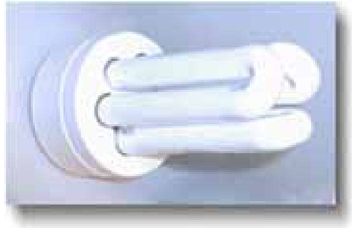
(Source: Energy Efficiency in Buildings: CIBSE Guide F)

Energy efficiency

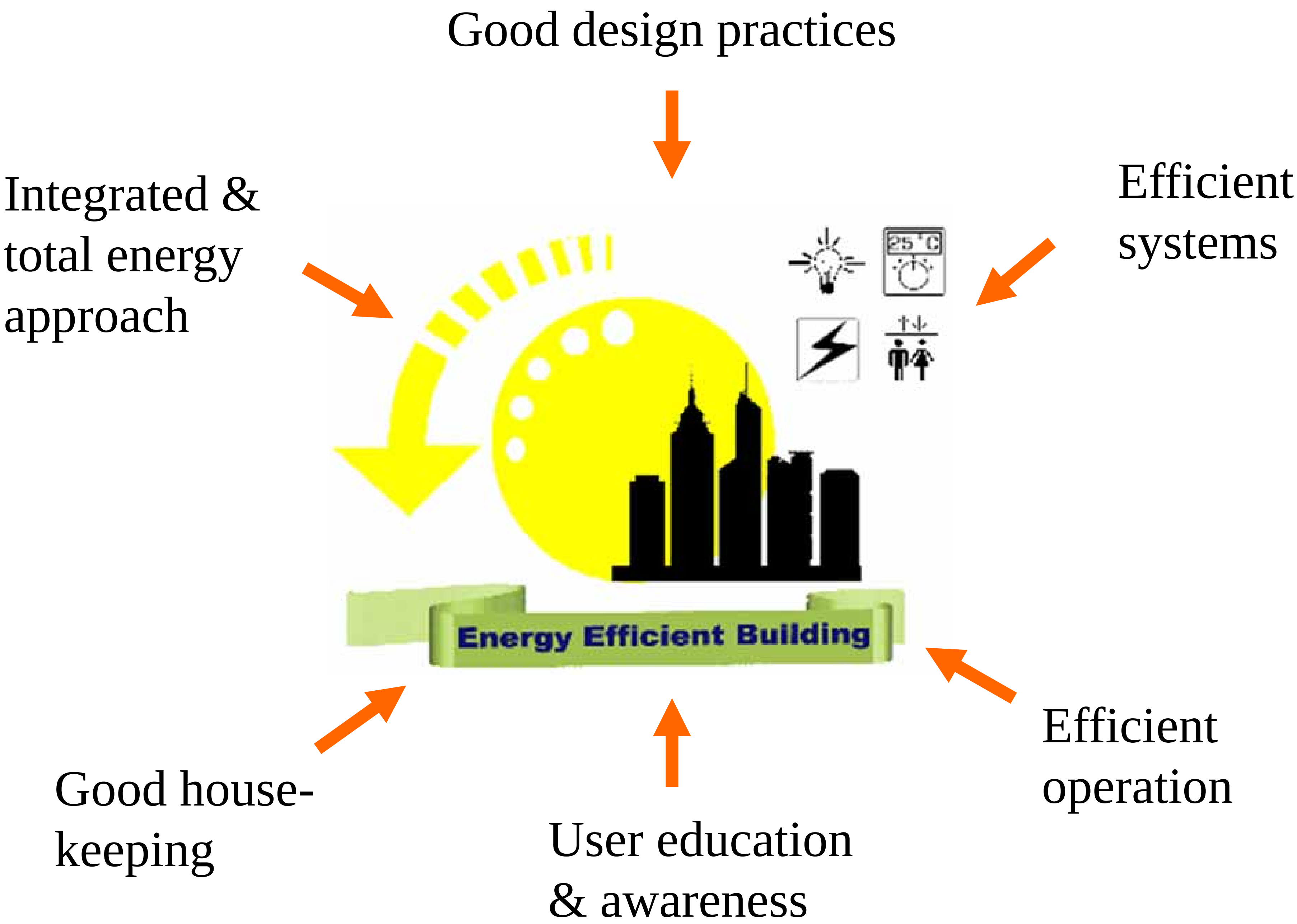


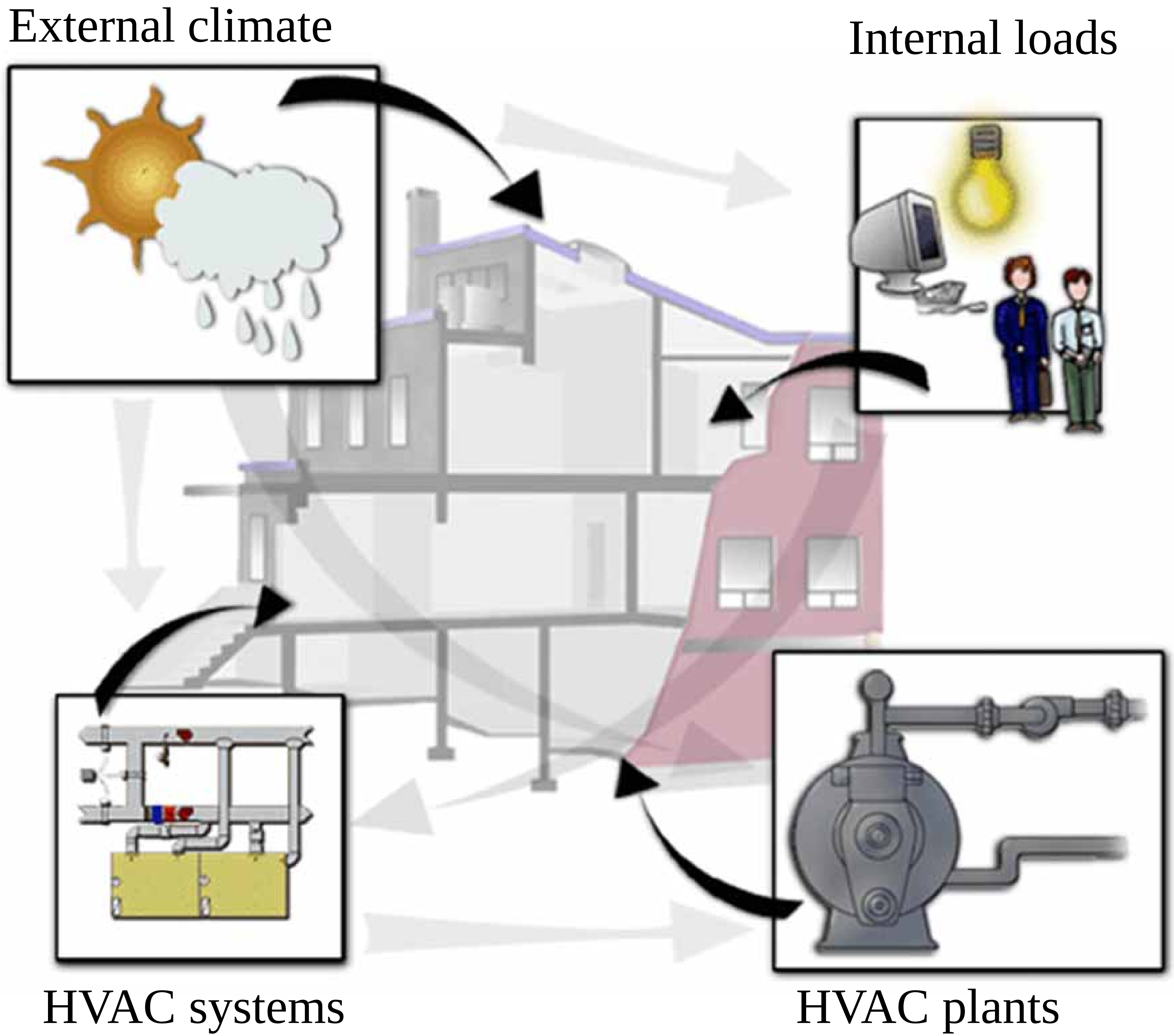
- Building energy efficiency codes
  - Building envelope, such as:
    - HK-OTTV standard
    - Overall thermal transfer value (OTTV)
  - Codes of Practice for building services systems
    - HVAC, lighting, electrical, lifts & escalators
  - Performance-based building energy code
- Become mandatory in 2011 in Hong Kong, under the Buildings Energy Efficiency Ordinance

Energy efficiency



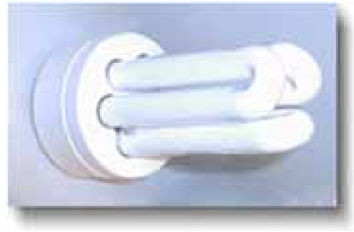
- Promote passive design and natural ventilation
  - e.g. bioclimatic buildings, passive cooling/heating
- Adopt energy efficient building services systems
  - Lighting, air-conditioning, electrical, lifts
- Needs to study thermal & energy performance
  - e.g. by computer simulation or energy audit
- Must also ensure efficient operation and management of the building
  - User education & awareness, good housekeeping


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

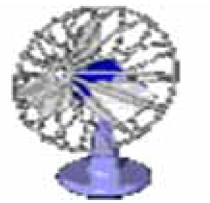


HVAC = heating, ventilation and air conditioning

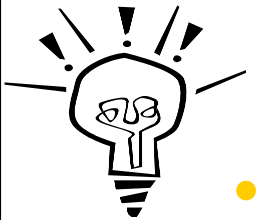
Energy efficiency



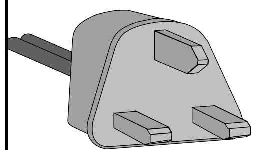
- Design strategies:



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



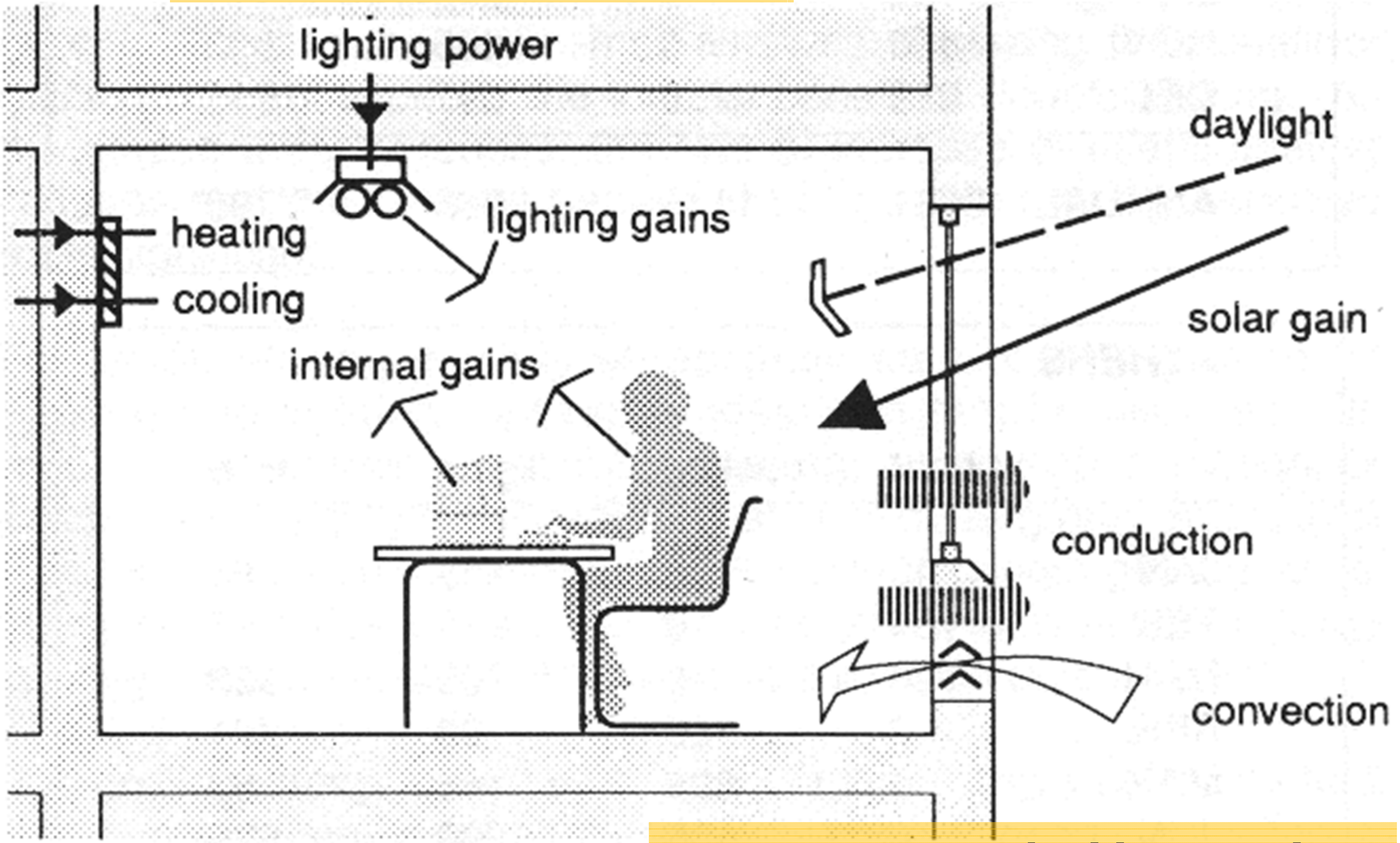
  - Optimise window design & fabric thermal storage
    - Integrate architectural & engineering design
  - Promote efficiency in building services systems



    - 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)

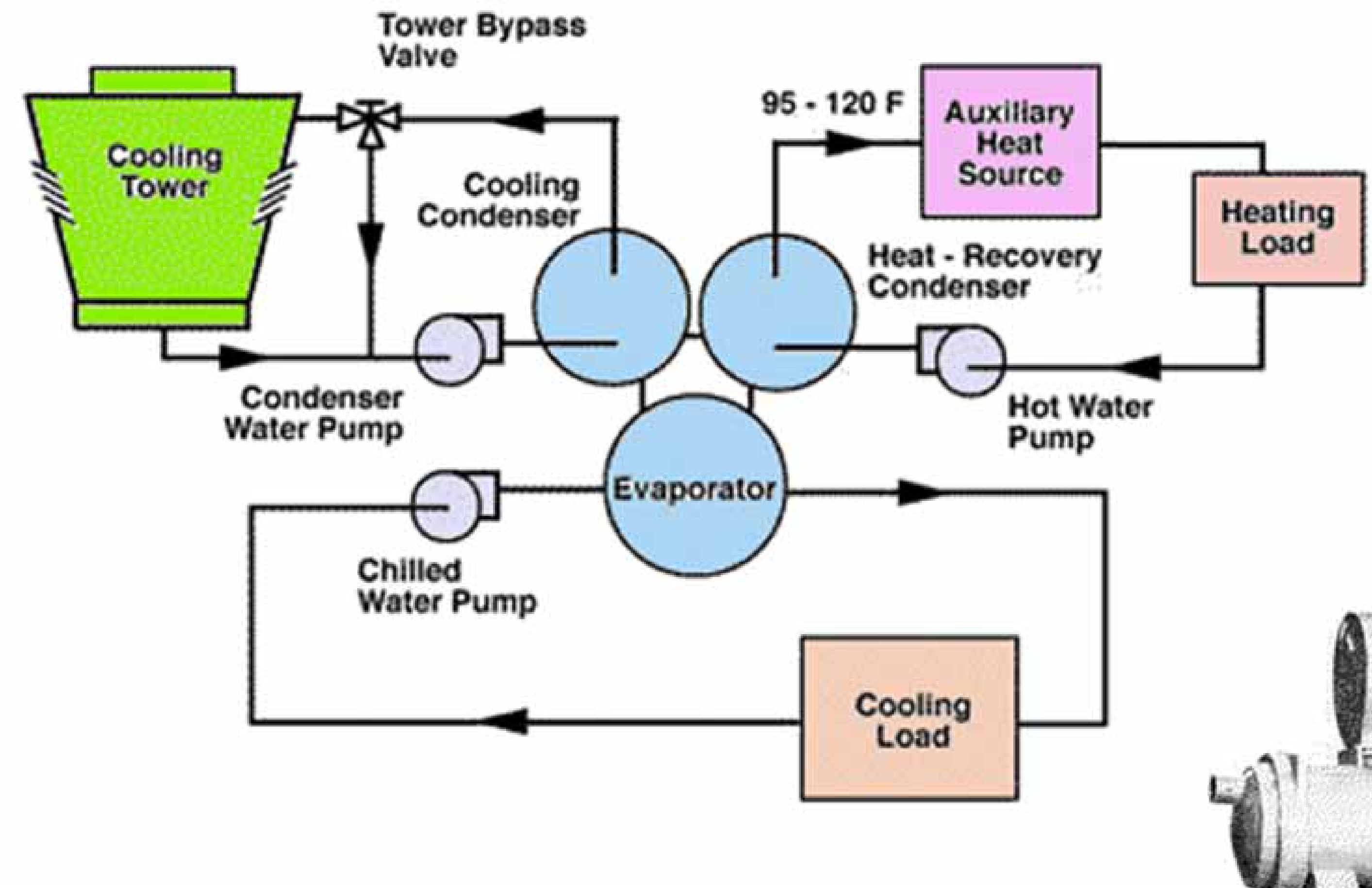
Strategy: reduce thermal loads



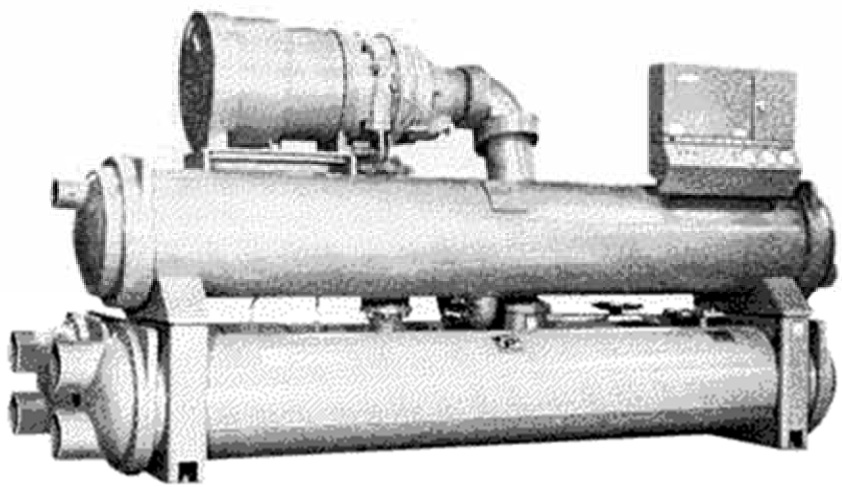
Strategy: optimise building envelope

Thermal energy balance in a building space

Strategy: use of heat recovery



Produce hot water or heating

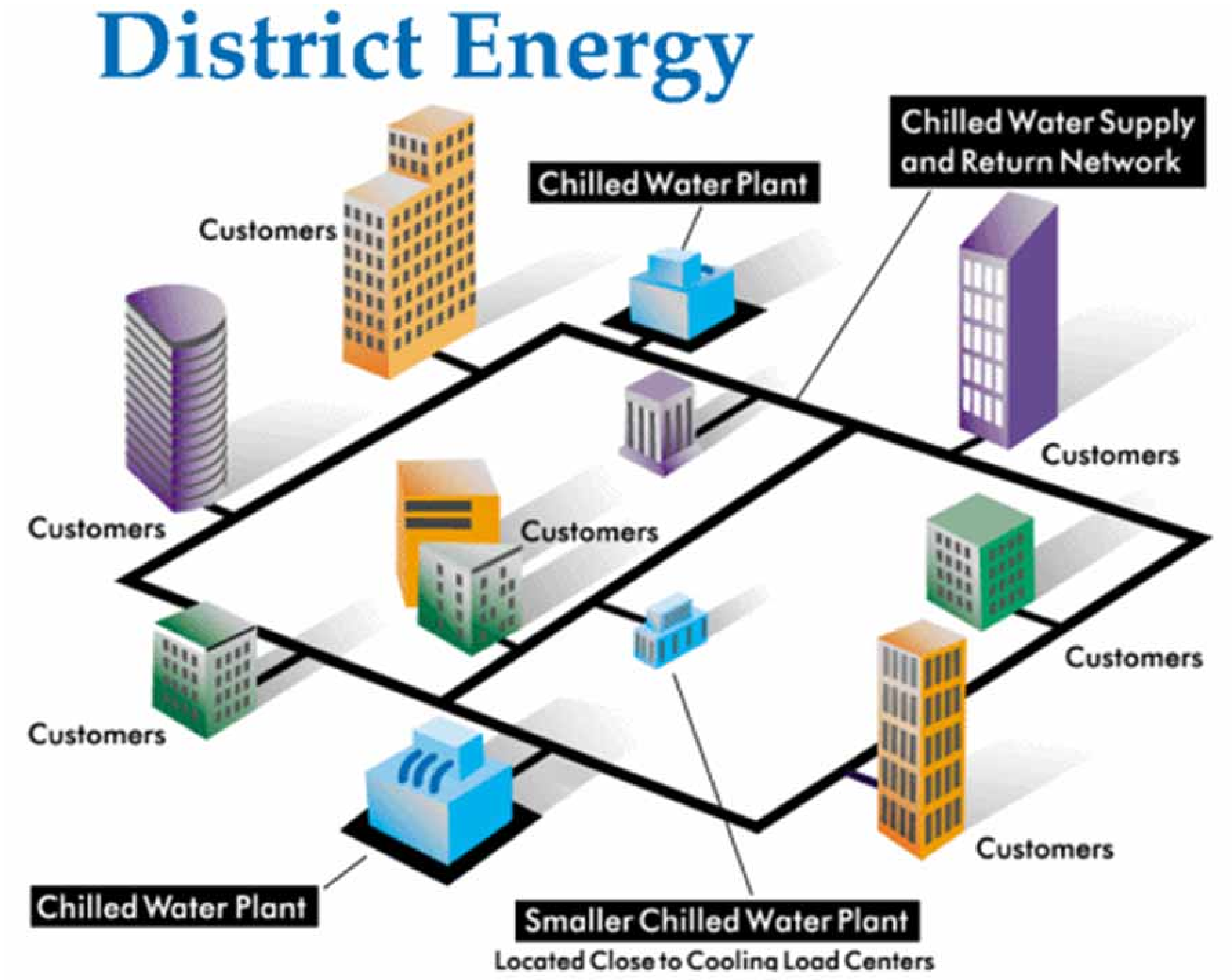


Double bundle heat recovery chiller

Waste heat recovery - double bundle heat recovery chiller

District cooling system (DCS)

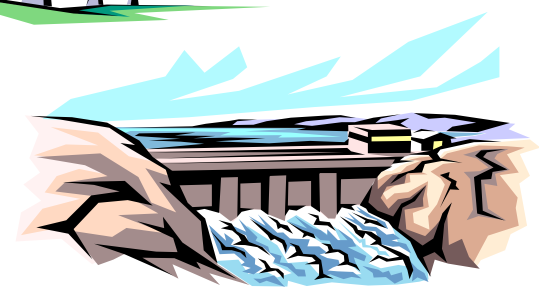
Strategy: total energy approach



(Source: www.entergy-thermal.com/district_energy)

Renewable energy

- Energy that occurs naturally and repeatedly on earth and can be harnessed for human benefit, e.g. solar, wind and biomass
- Common applications
  - Solar hot water
  - Solar photovoltaic
  - Wind energy
  - Geothermal
  - Small hydros

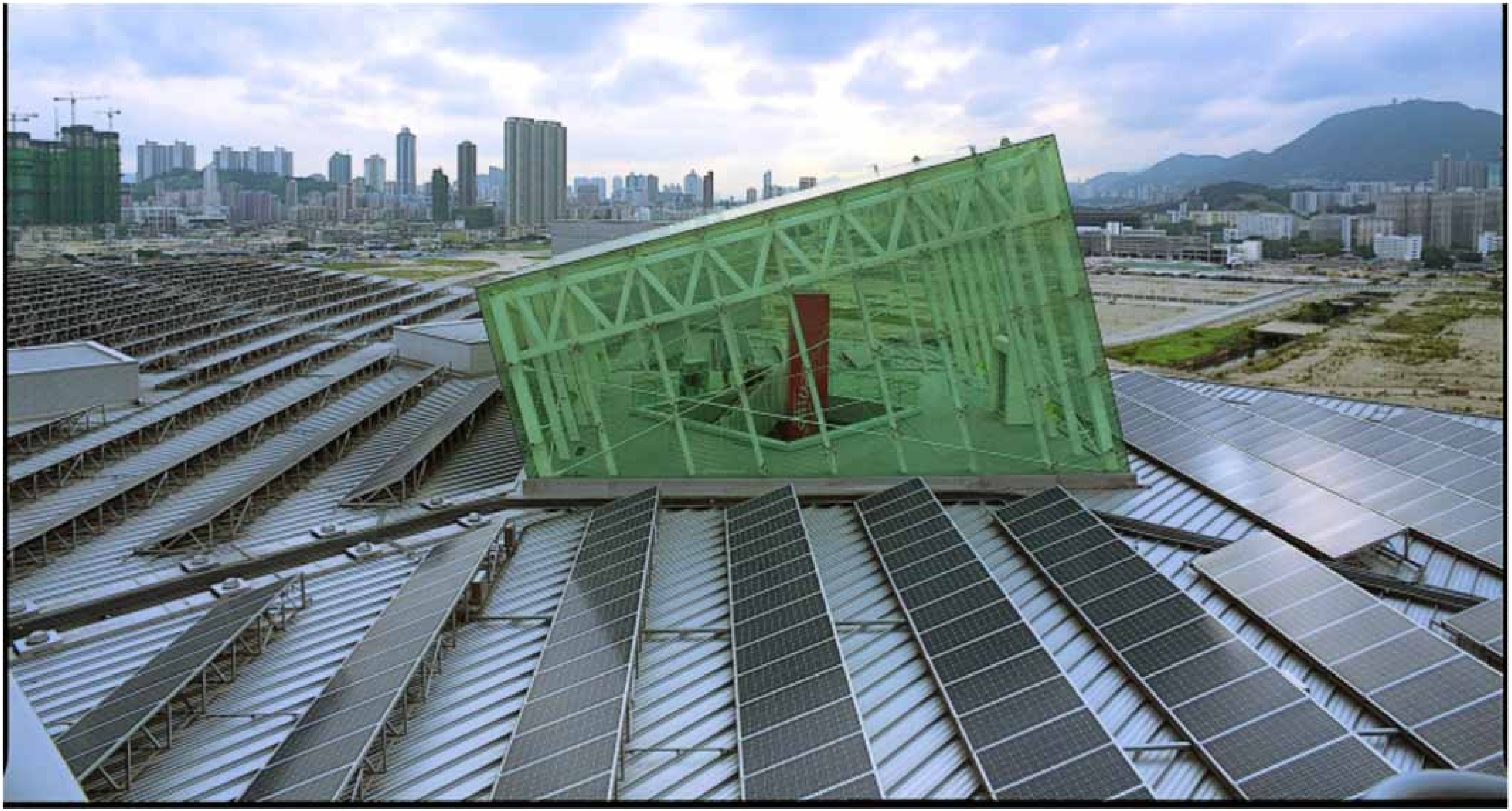


可再生能源

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 thermal systems in Hong Kong



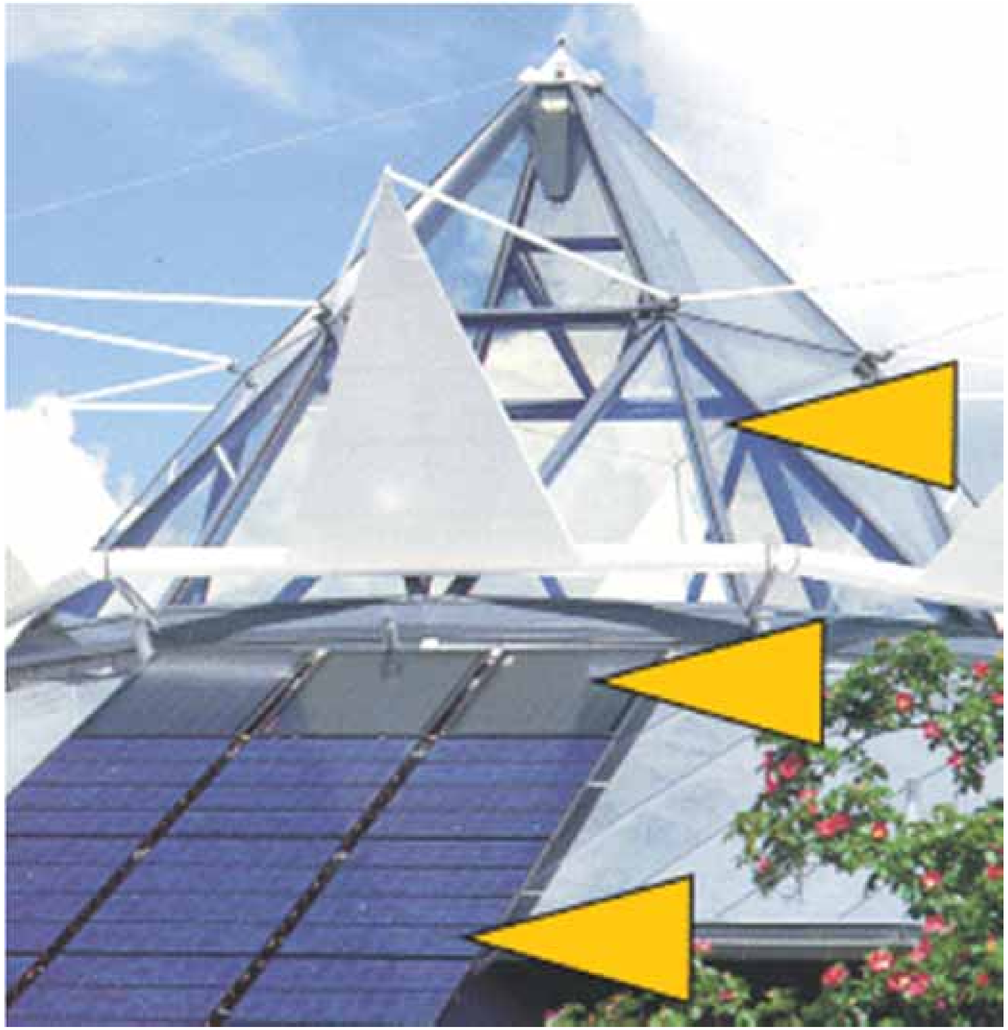
A 350 kW solar photovoltaic (PV) installation installed on the roof of the EMSD Headquarters in Kowloon Bay (2,300 PV modules with a total area of 3,180 sq.m) [Source: EMSD]

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。



Passive solar (e.g. skylight)

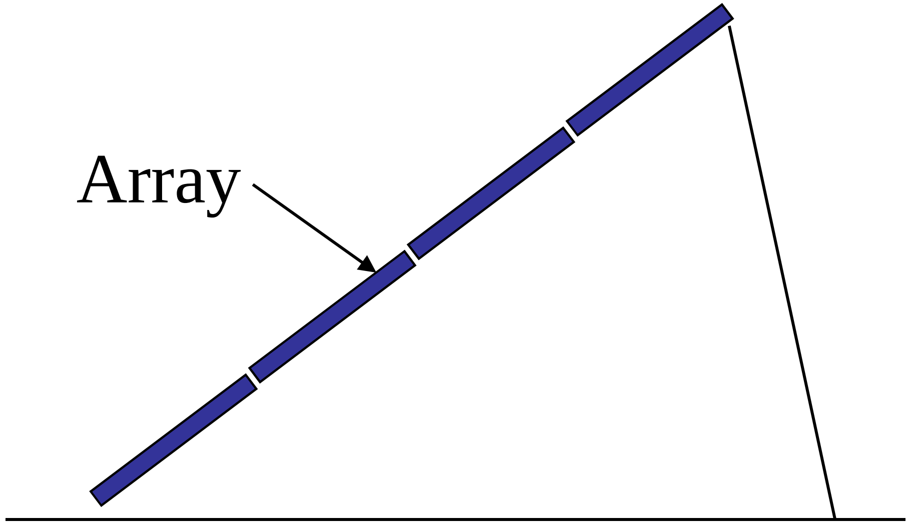
Active solar (solar hot water)

Photovoltaics

Integration of solar energy systems in buildings

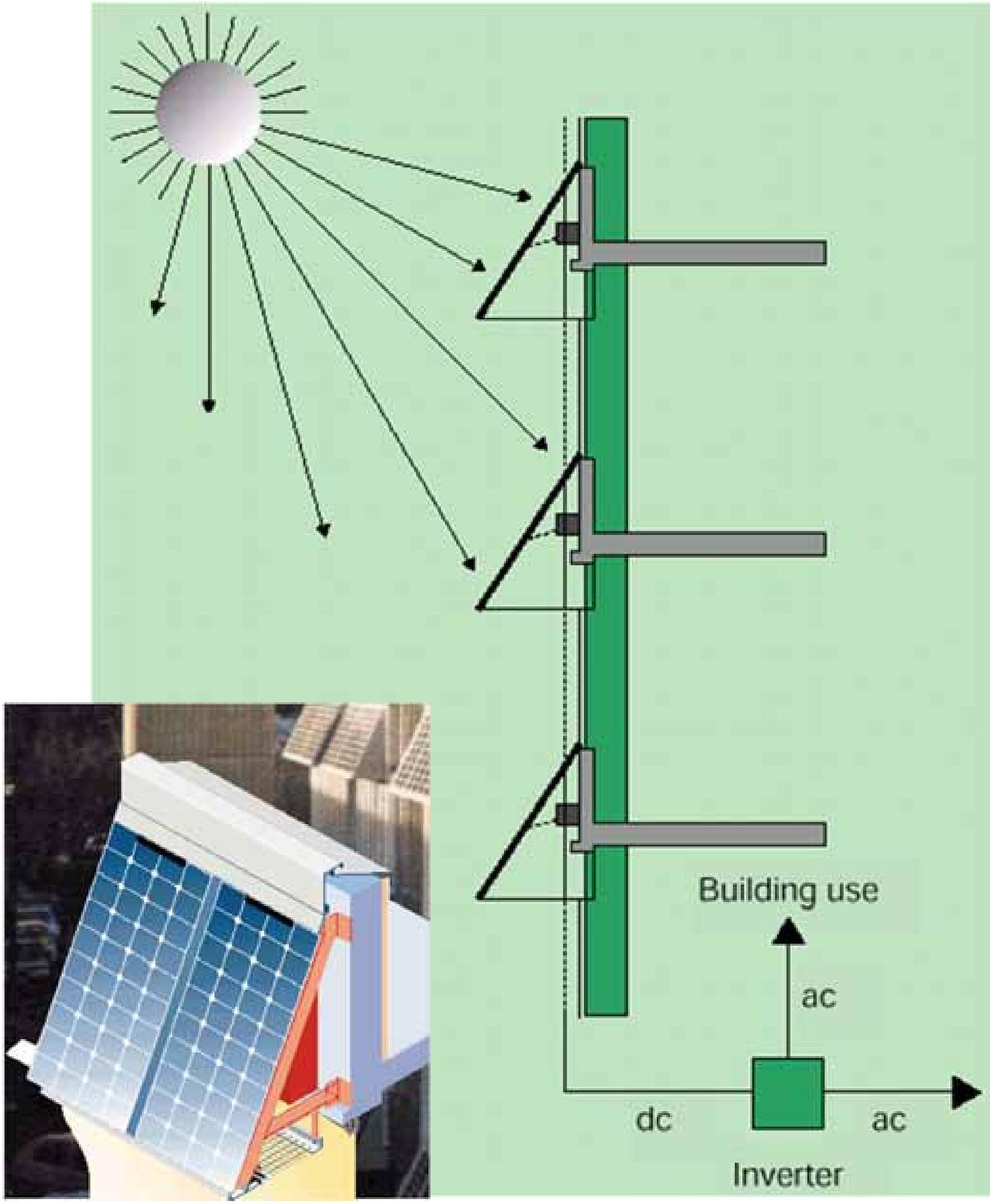
Evacuated-tube solar hot water system in a hotel in Lhsa, Tibet
(photo taken by Dr Sam C M Hui)

* Locate array in an unshaded area facing the equator



Tilt angle
= latitude (^{o}) + 15^o

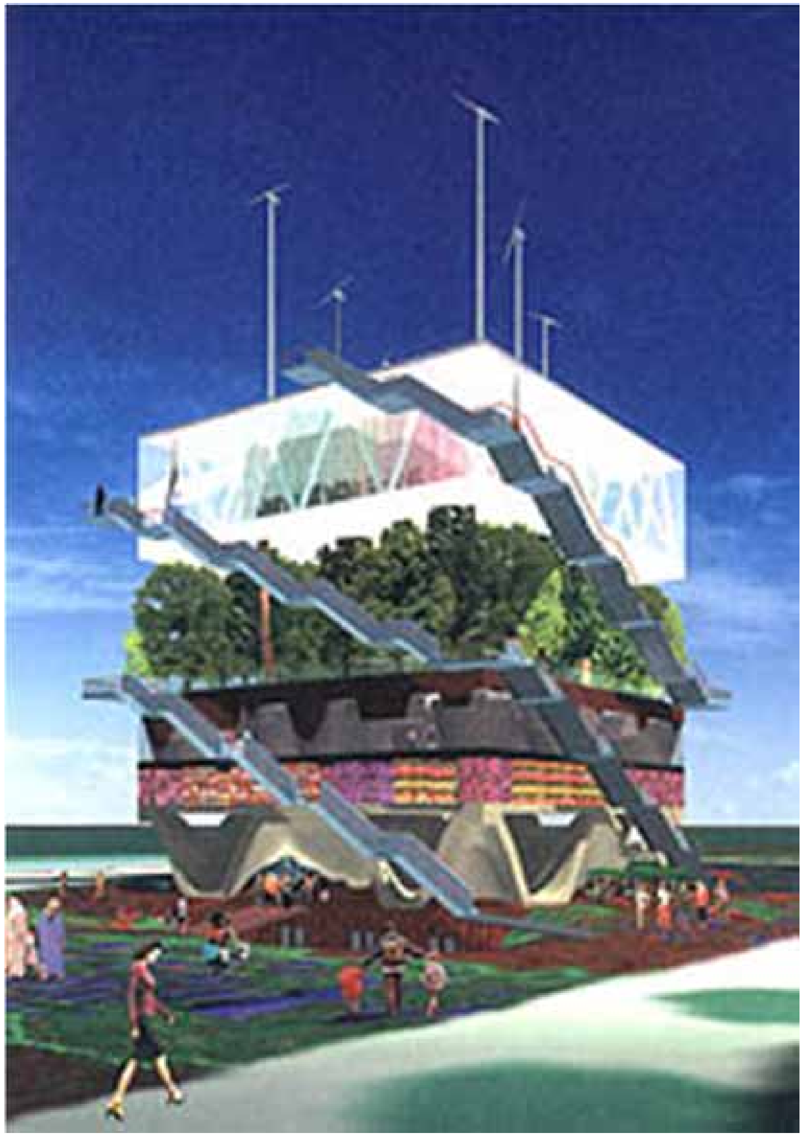
(a) Roof (horizontal)



(b) Facades (vertical)

PV installations in buildings

Innovative ideas for building integrated renewable energy



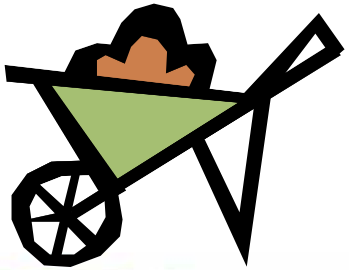
Dutch pavilion,
EXPO 2000 Hannover

Project Zed - London

Building integrated wind turbines (proposed WTC towers in Bahrain)

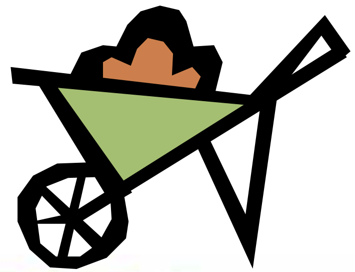
Pearl River Tower,
Guangzhou

Building materials



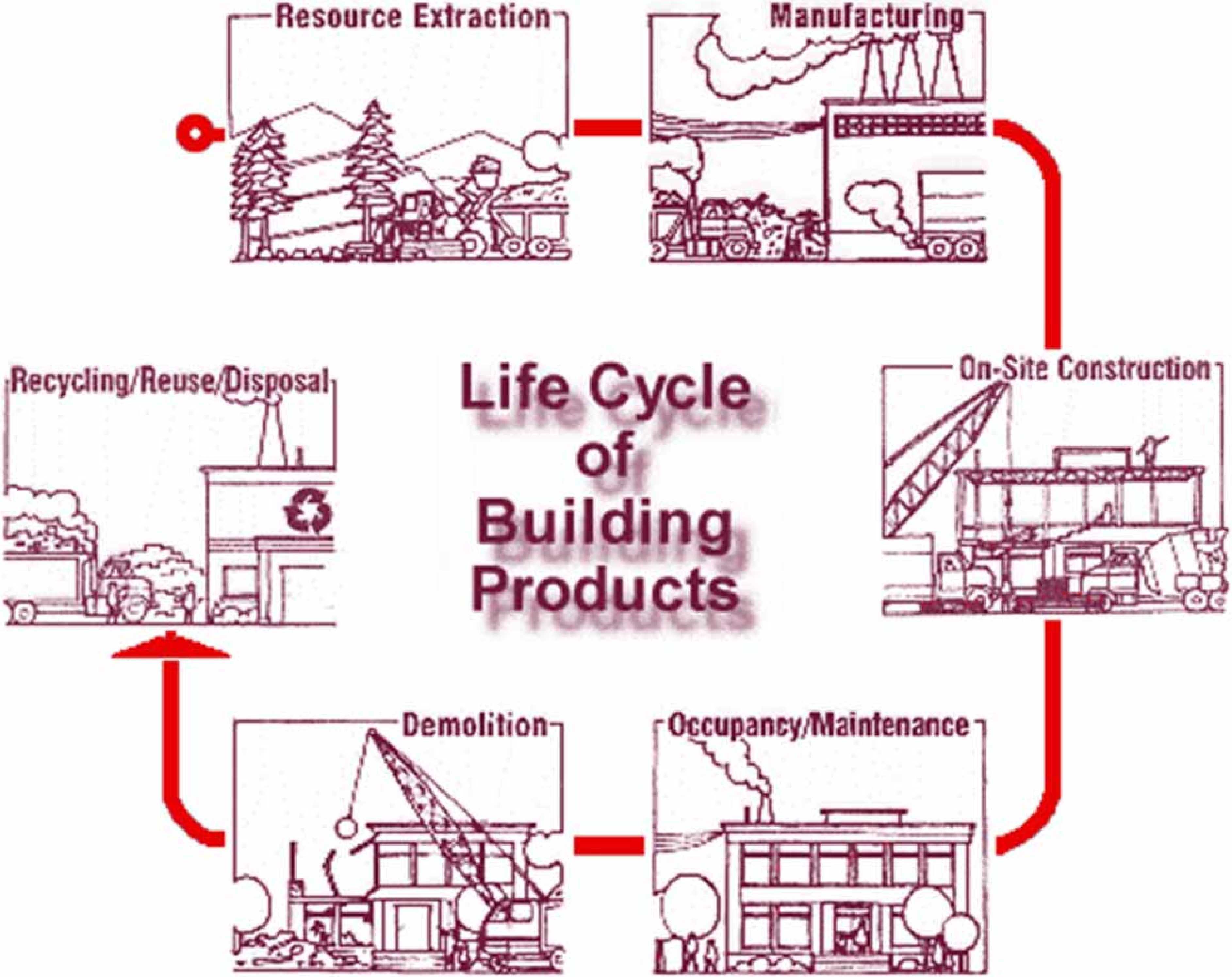
- Environmental impact of building materials
  - Through consumption of resources
  - Through production of resources (by-products, wastes, pollution, recyclables)
- Objectives
  - Make informed environmental choices about building materials and systems
  - Careful design & understanding about materials

Building materials



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

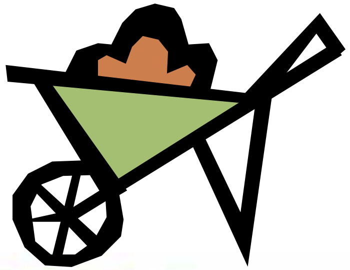
[* http://en.wikipedia.org/wiki/Embodied_energy]


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

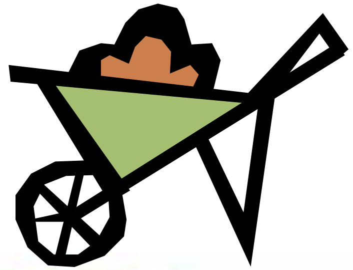


- Specify green materials & products
  - Made from environmentally attractive materials
    - Such as reclaimed, recycled or recyclable products
  - That reduce environmental impacts during construction, renovation, or demolition
  - That reduce environmental impacts of building operation
  - That contribute 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**)	

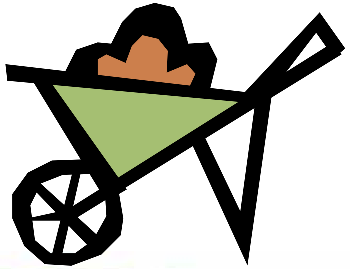
Building materials



- 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

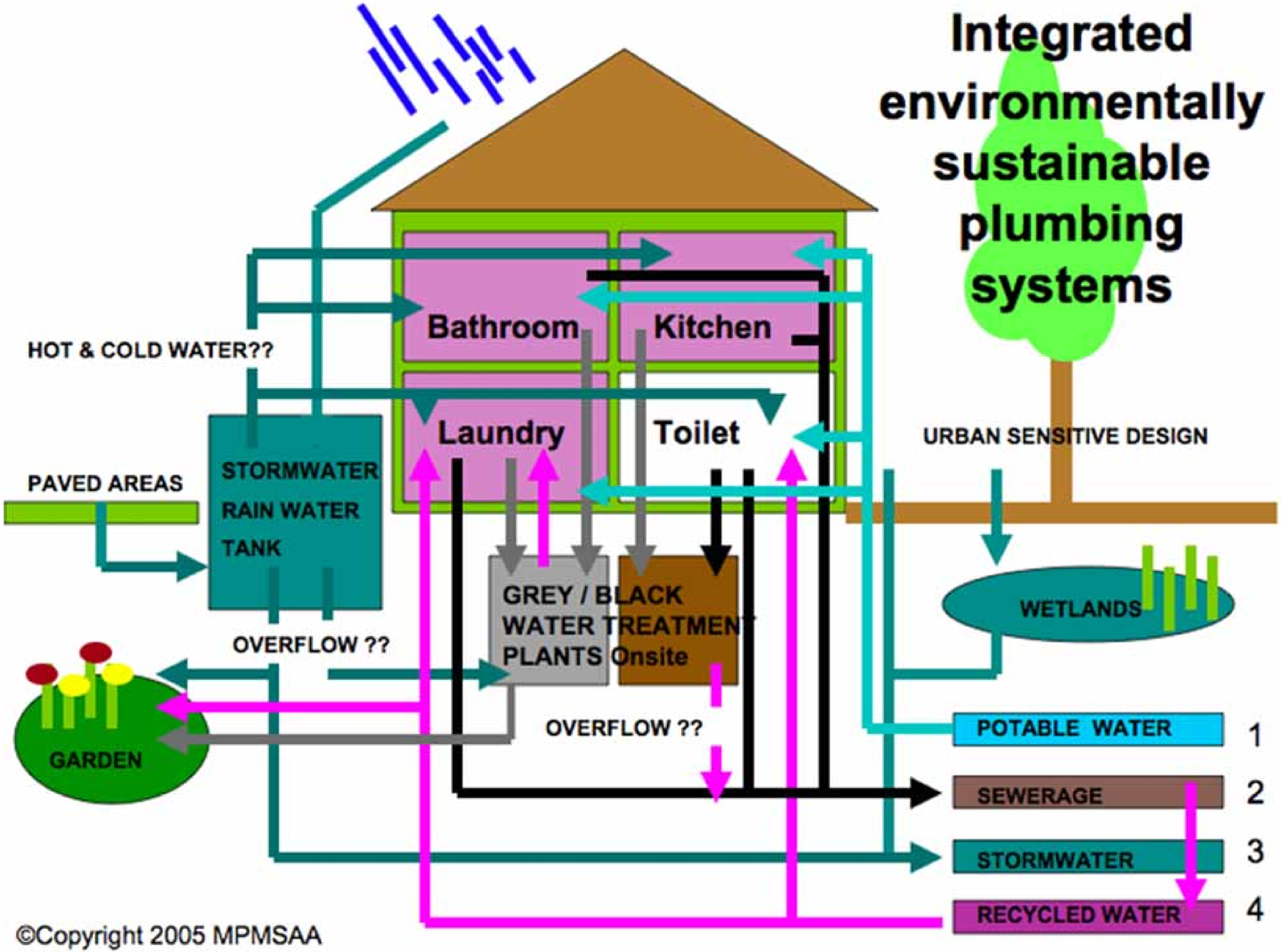


- Waste management strategies
  - Waste prevention & reduction
  - Construction and demolition recycling
  - Architectural reuse
  - Design for material recovery
- Important factors
  - On-site collection & storage space
    - In HK, the space is very limited
  - Sorting & separation (paper, glass, plastic,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

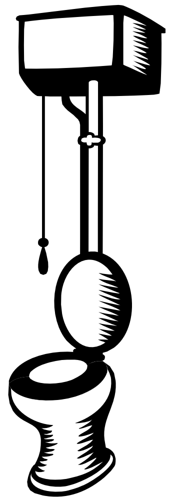
- Water efficiency and conservation
  - Saving of water and money: water-use charge, sewage treatment costs, energy use, chemical use

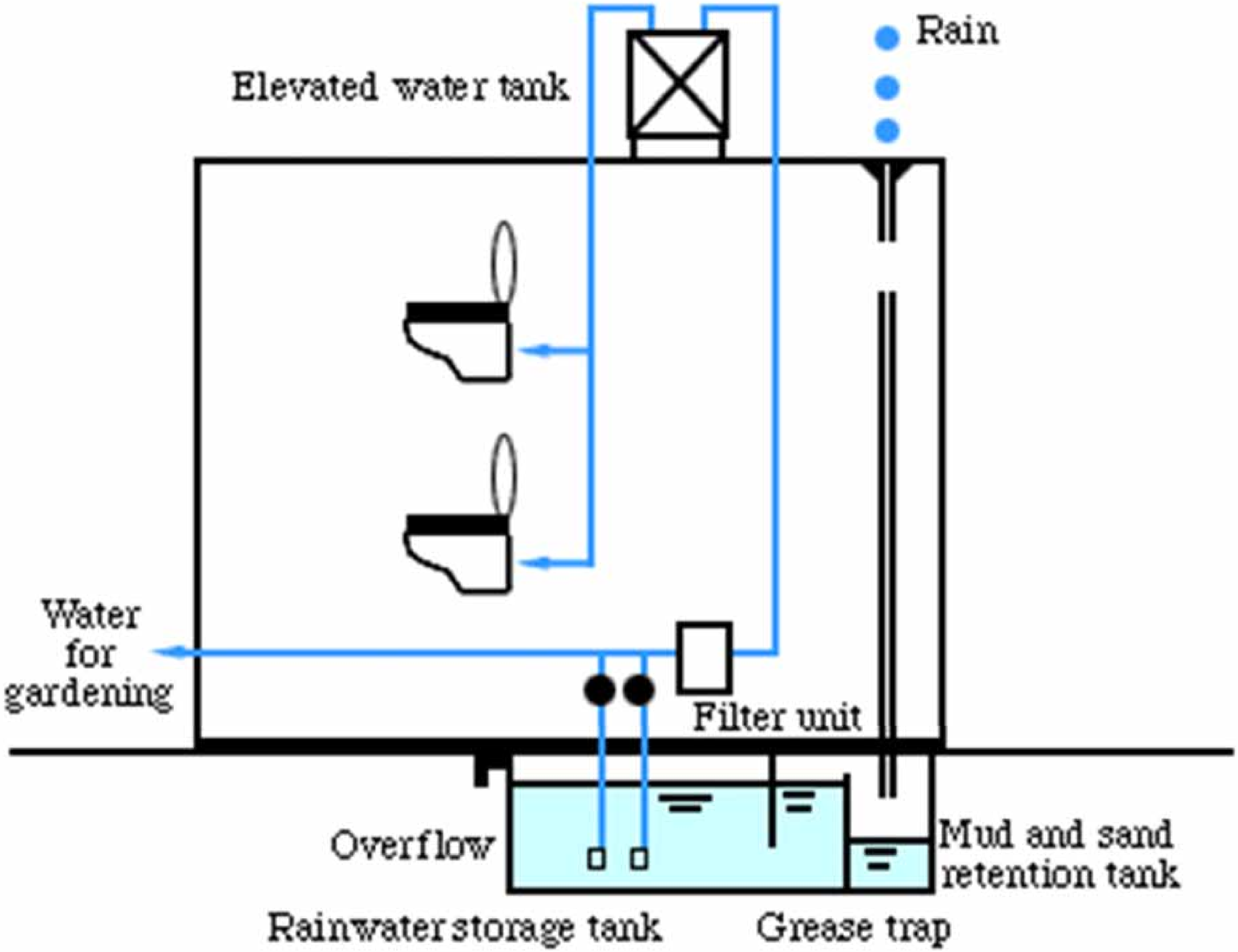


Integrated environmentally sustainable plumbing systems
Bathroom
Kitchen
Laundry
Toilet
HOT & COLD WATER??
PAVED AREAS
STORMWATER
RAIN WATER
TANK
GREY / BLACK
WATER TREATMENT
PLANTS Onsite
OVERFLOW ??
OVERFLOW ??
GARDEN
URBAN SENSITIVE DESIGN
WETLANDS
POTABLE WATER
1
SEWERAGE
2
STORMWATER
3
RECYCLED WATER
4
©Copyright 2005 MPMSAA

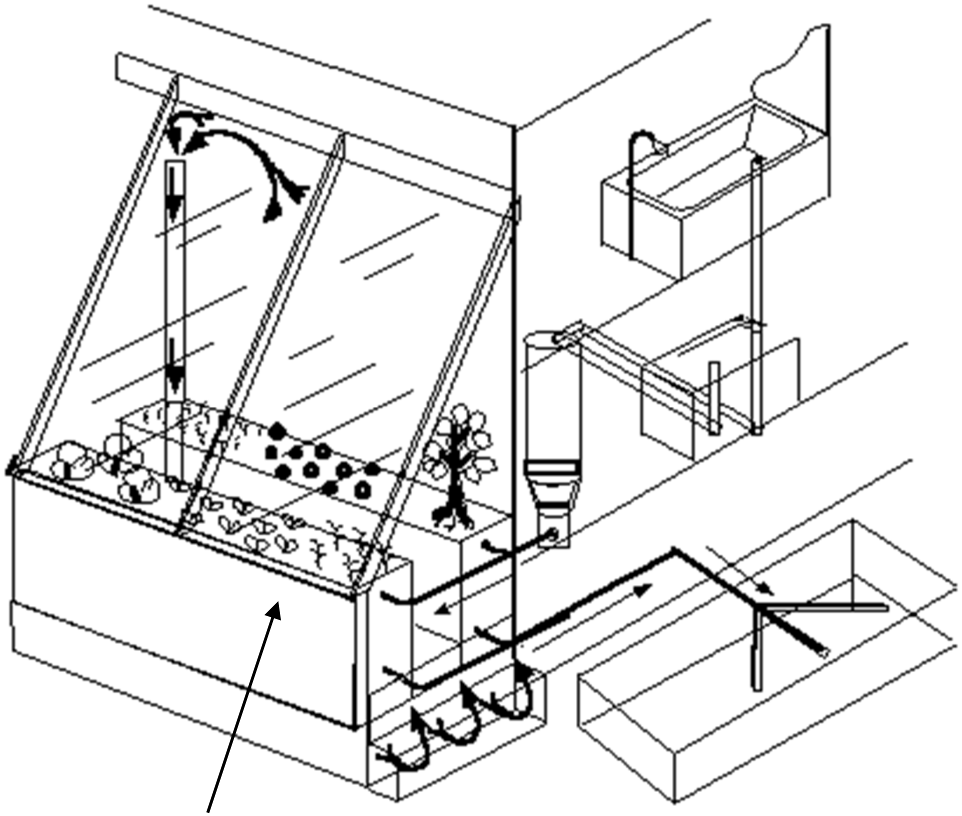
Water issues

- 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

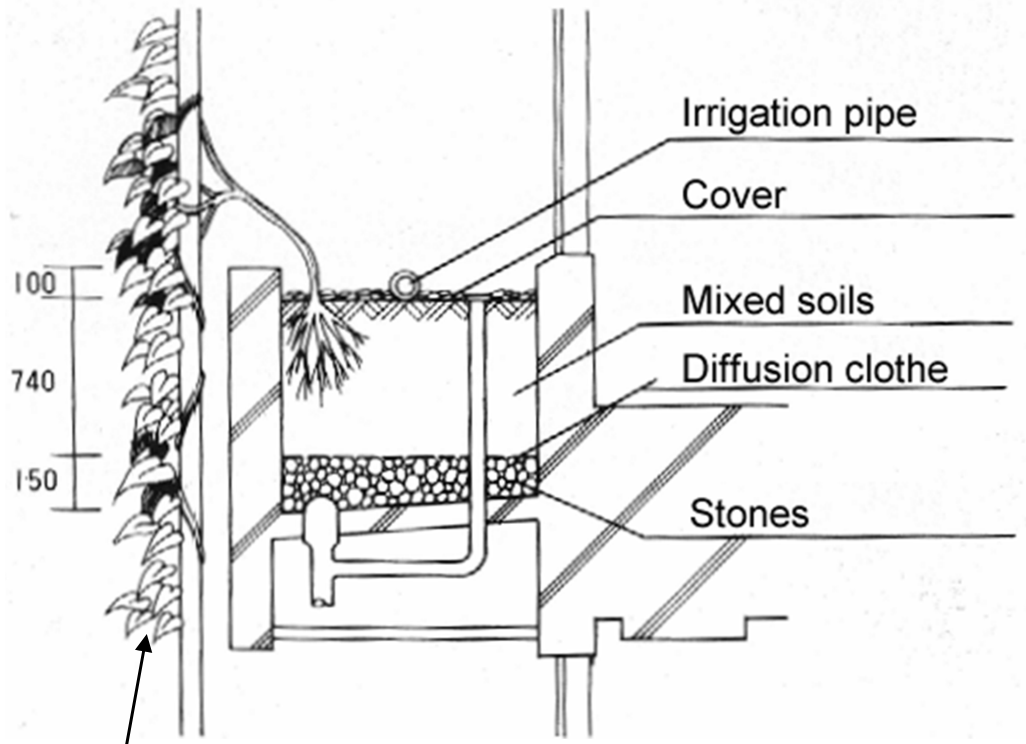




Rainwater recycling system

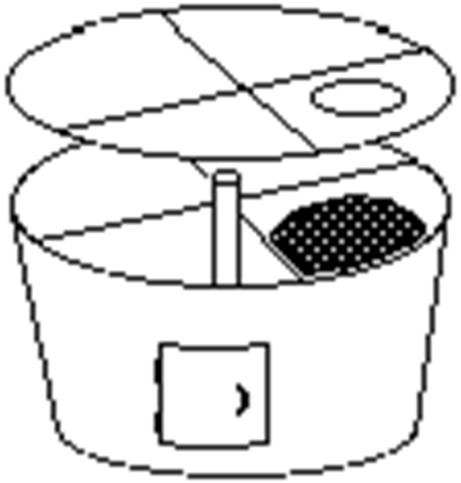


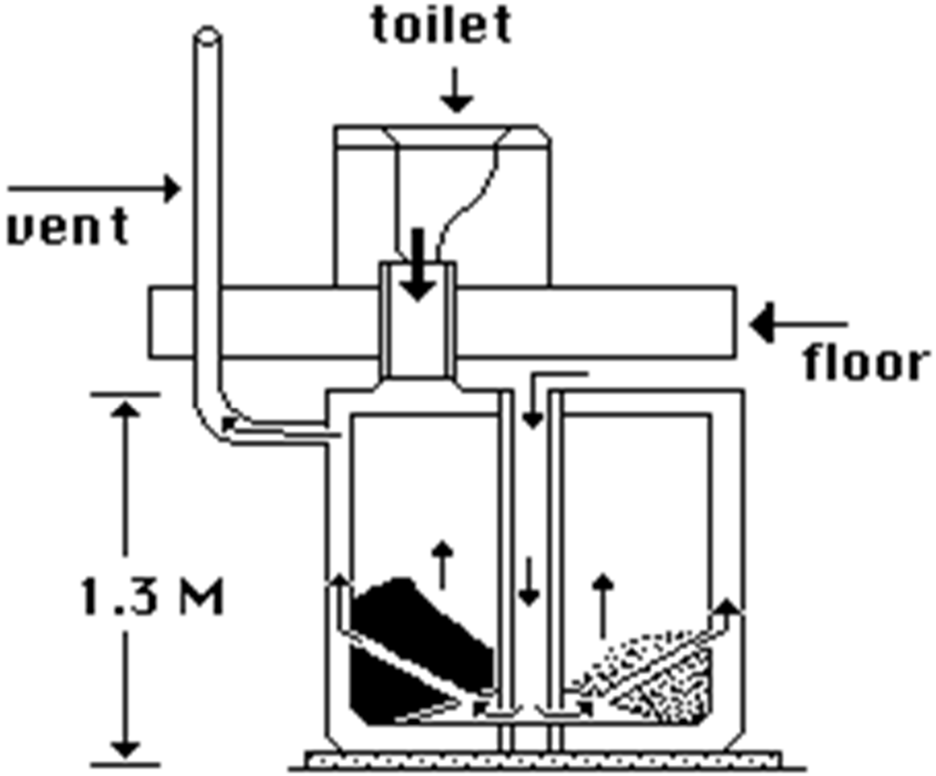
Crops growing
(for food or flowers)



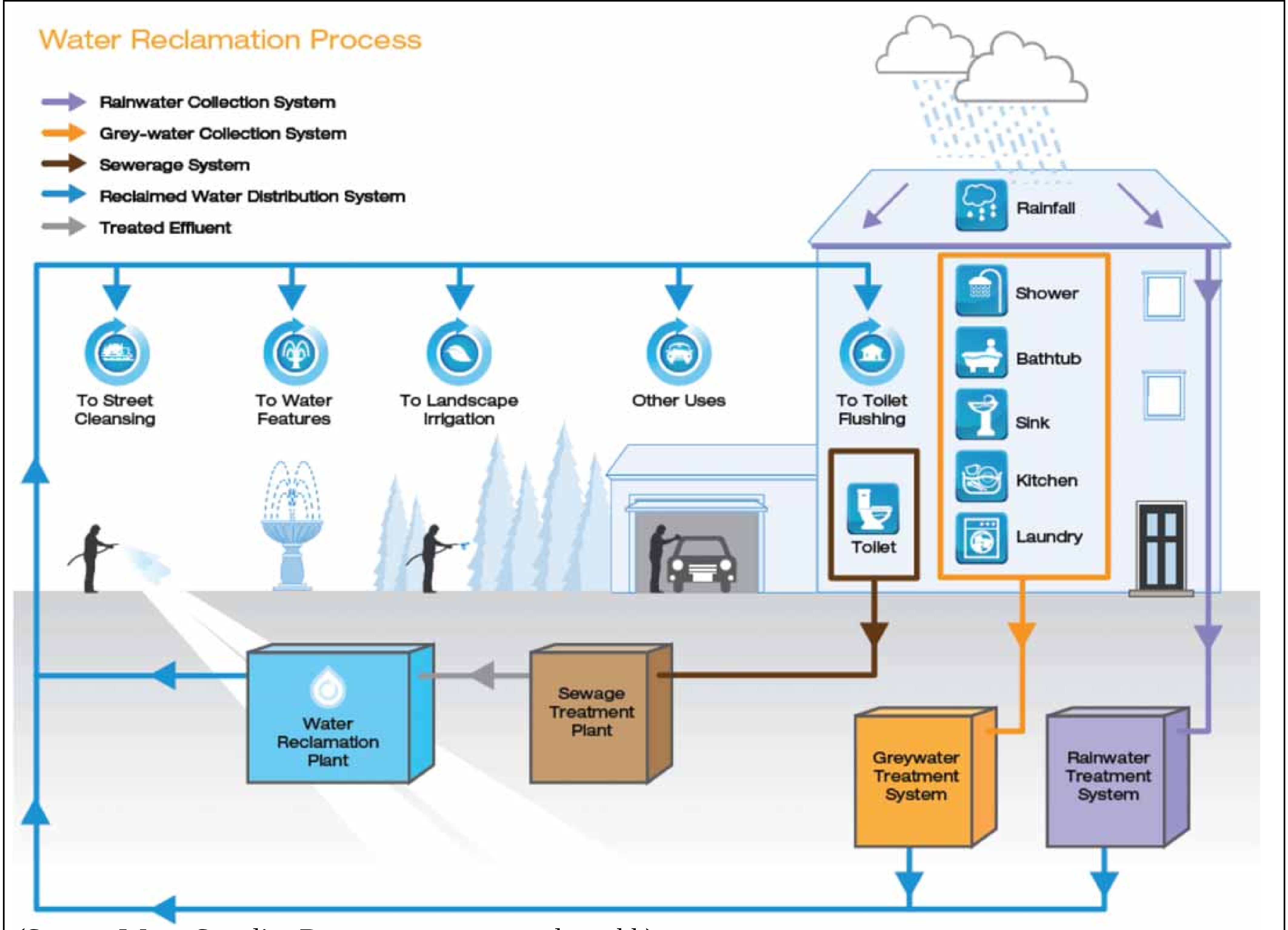
Espalier

Using greywater for crops and landscape irrigation



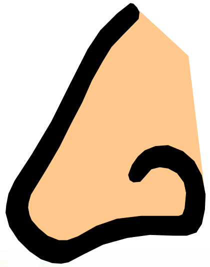


Composting toilets



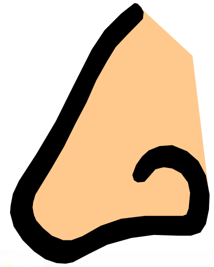
(Source: Water Supplies Department, www.wsd.gov.hk)

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

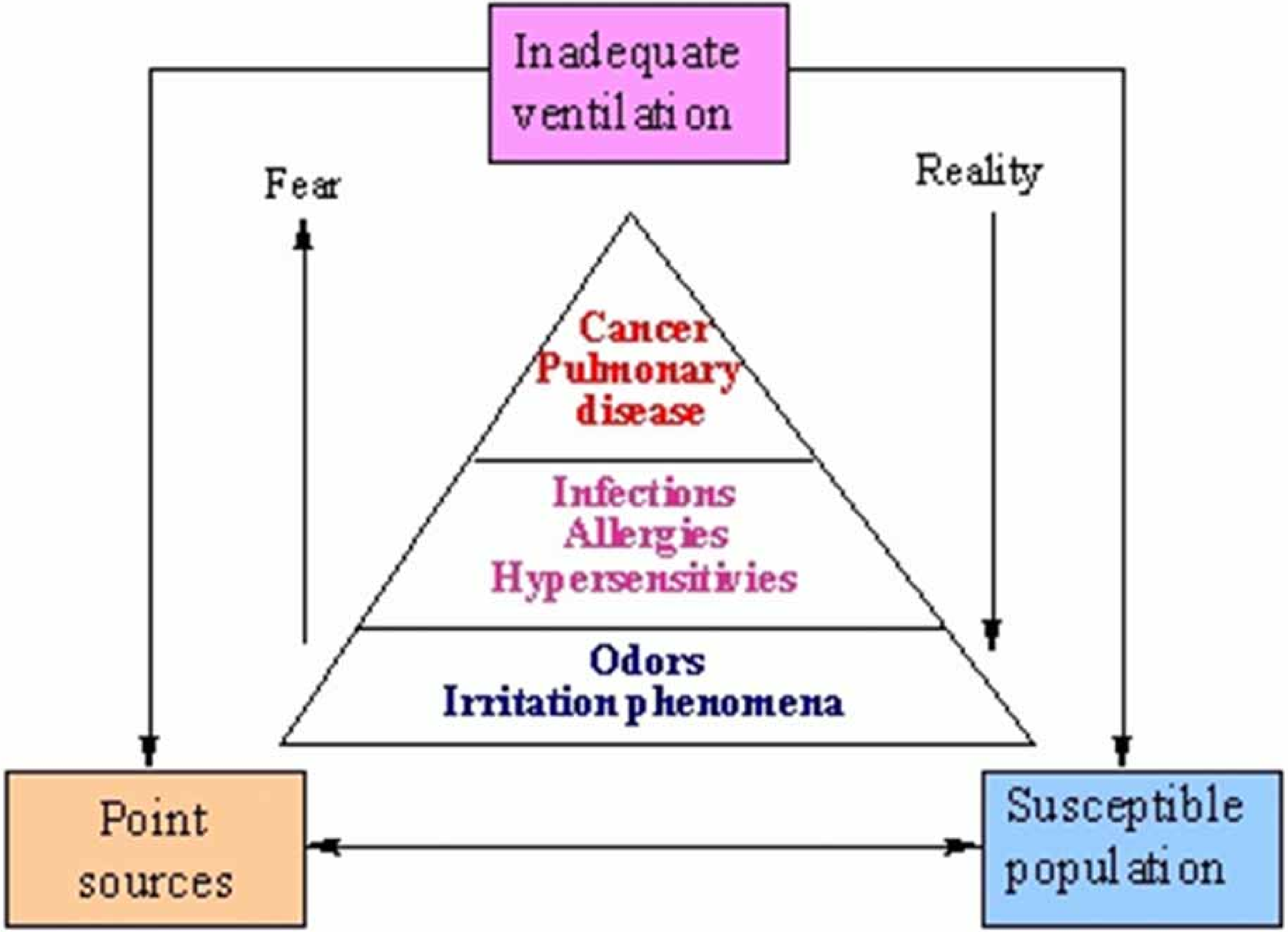
Indoor environment



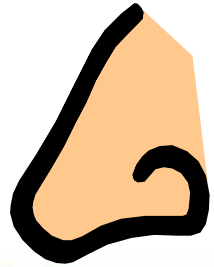
- Indoor air quality (IAQ)
  - People spend most of their time indoors
  - Pollutants may build up in an enclosed space
  - Effects on health and productivity
- Control methods
  - Assess materials to avoid health hazards
    - Such as volatile organic compounds (VOC)
  - Ensure good ventilation & building management

Understanding Indoor Air Quality Problems

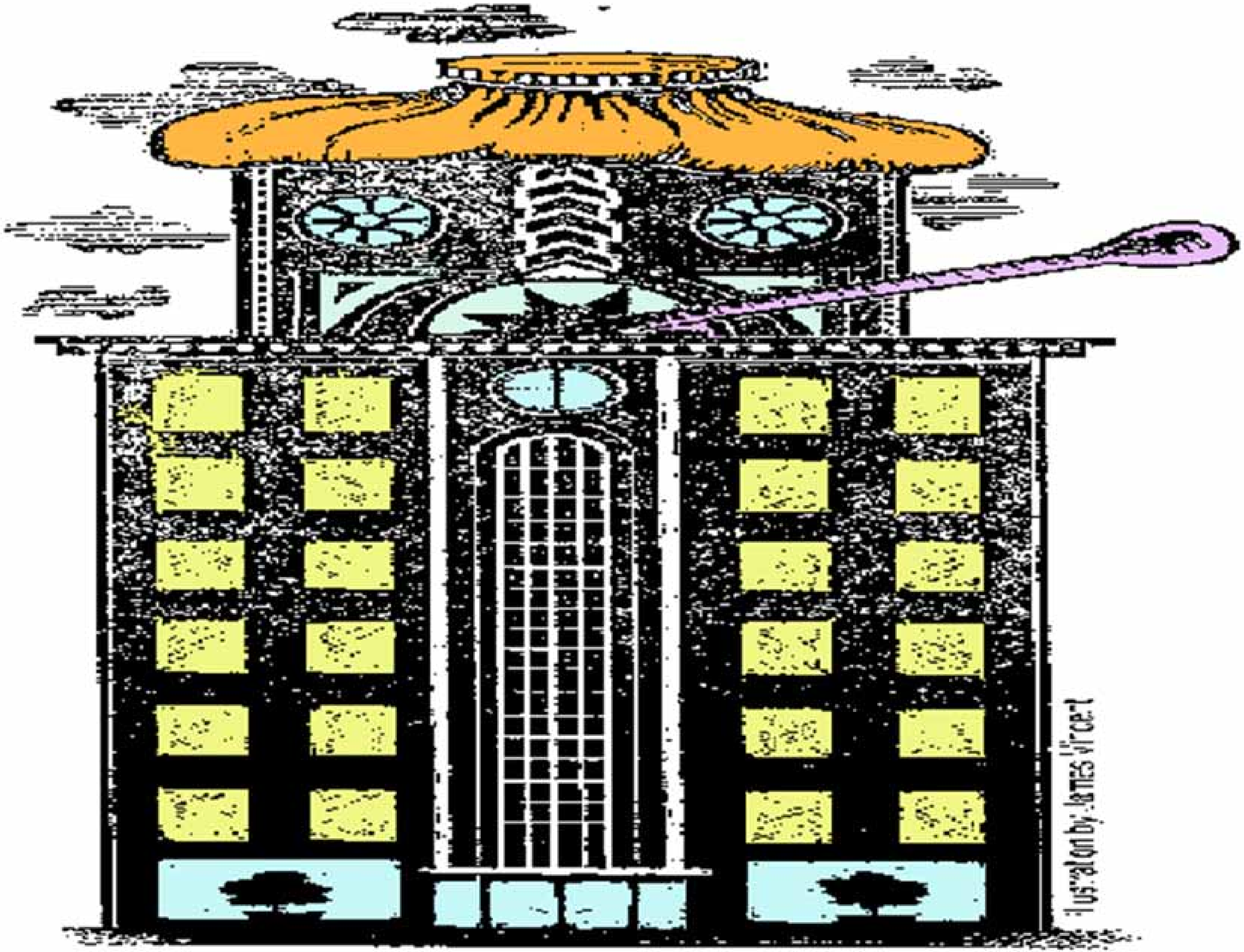
(Brooks & Davis, 1992)



Indoor environment

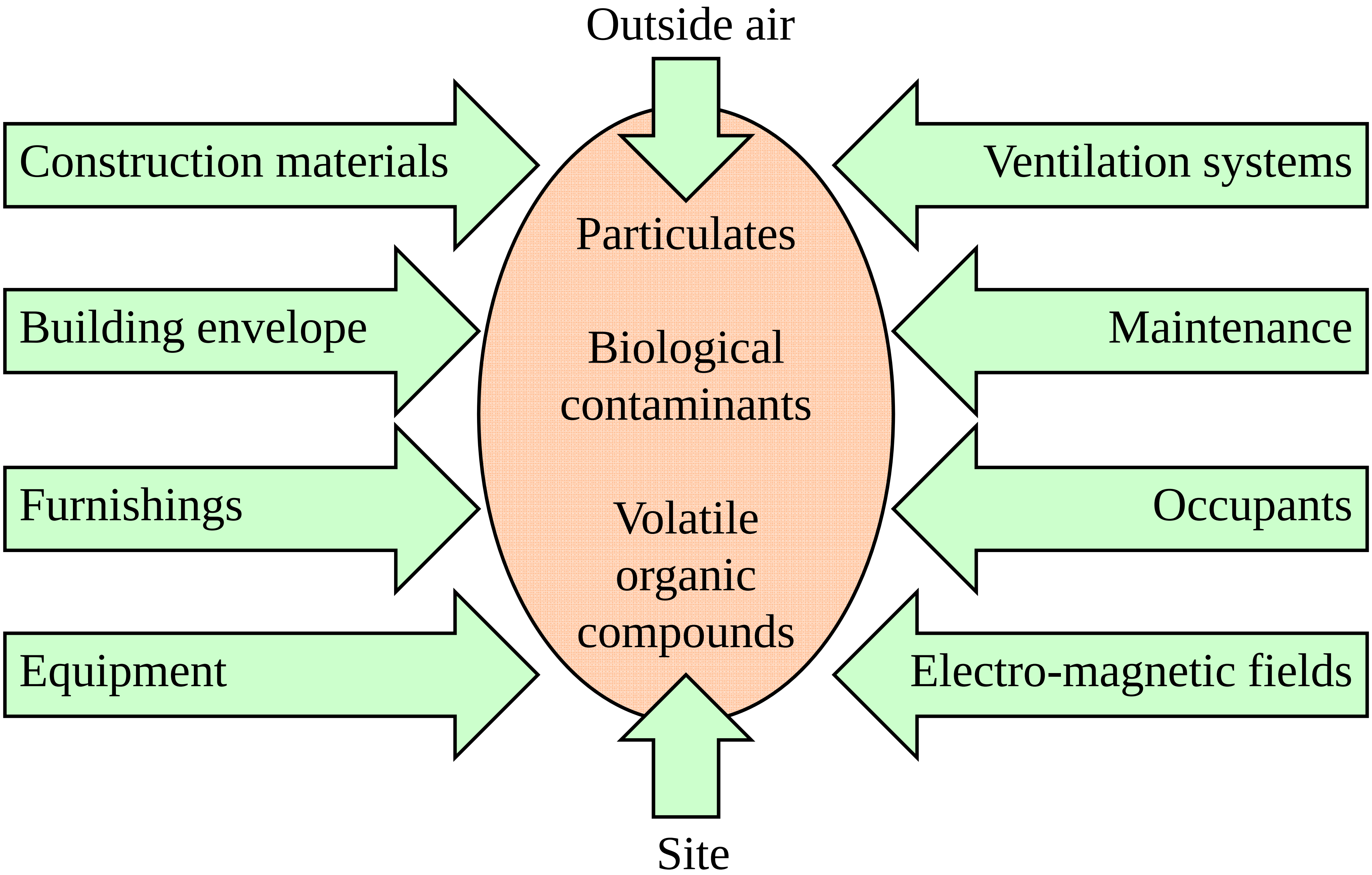


- IAQ problems
  - Not simple, and is constantly changing interaction of complex factors including:
    - Source of pollutants or odours
    - Maintenance and operation of ventilating systems
    - Moisture and humidity
    - Occupant perceptions and susceptibilities (e.g. elderly)
    - Other psychological 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

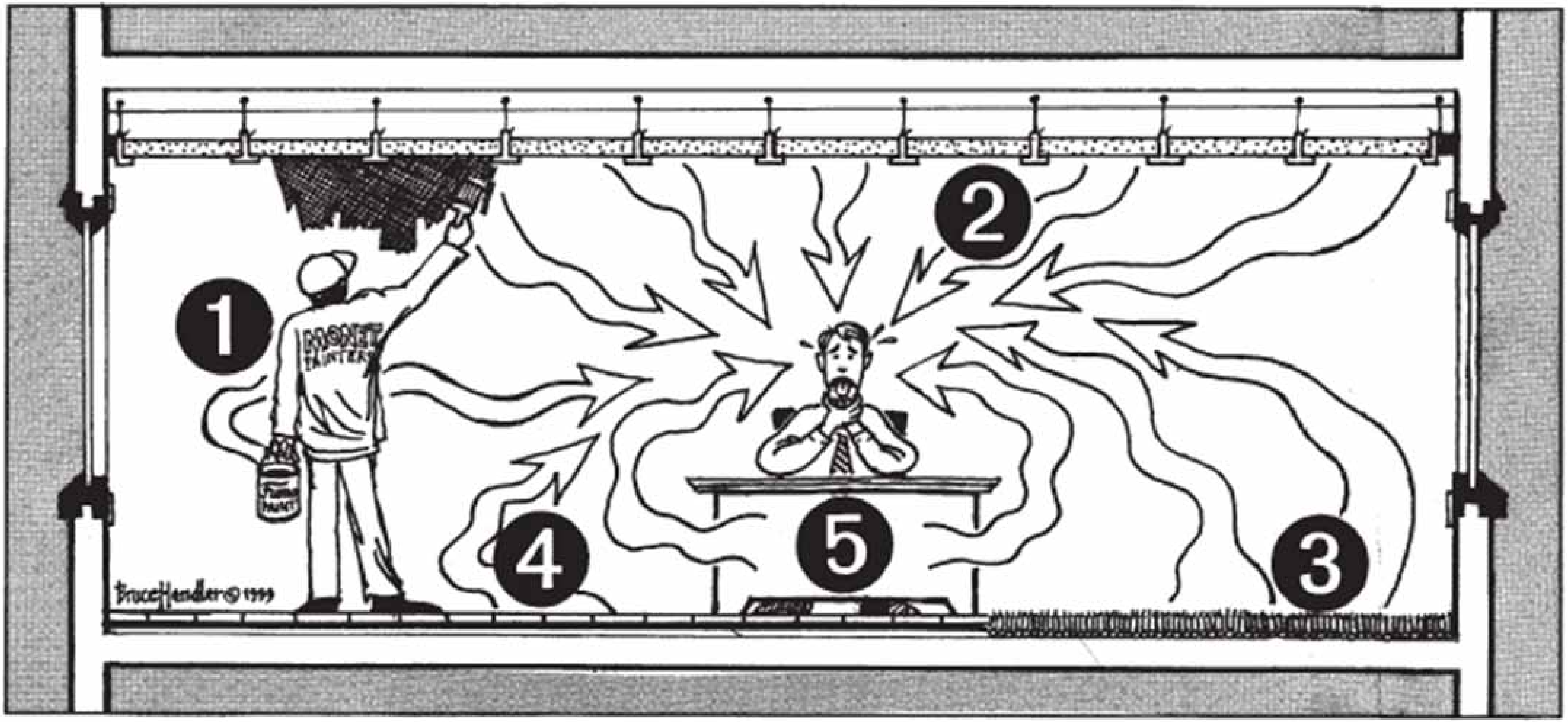
=

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

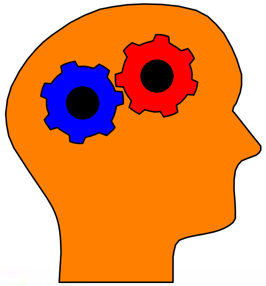


Sources of offgassing in building materials:
1) paints, 2) ceiling tiles, 3) carpeting, 4) VCT floor tiles
5) manufactured wood products

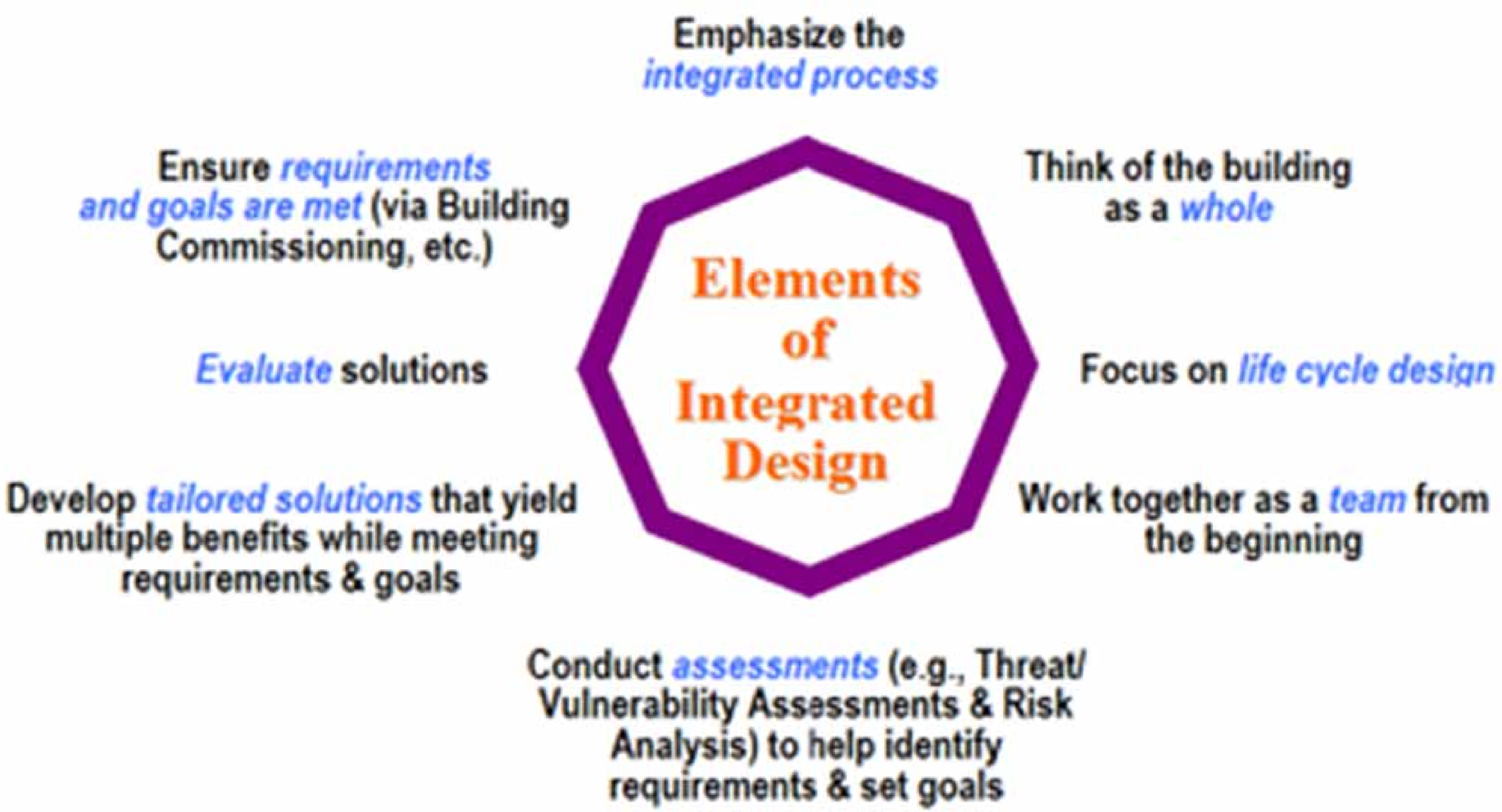
Indoor environment

- 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
  - www.wbdg.org
- 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*"

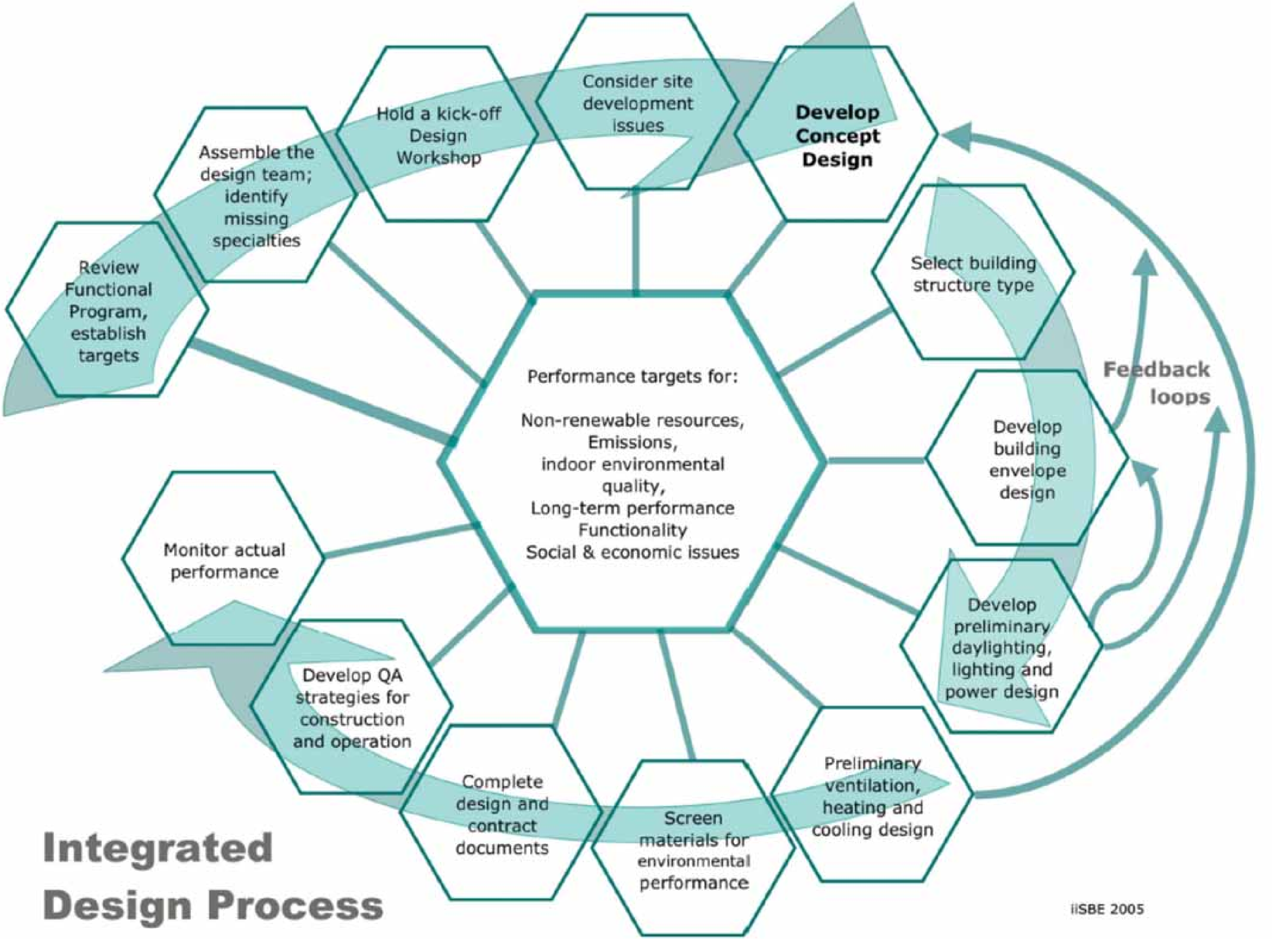


(Source: www.wbdg.org)

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

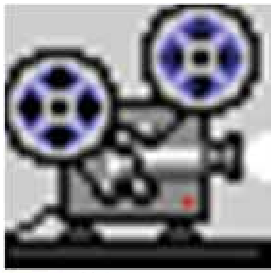


(Source: International Initiative for a Sustainable Built Environment (iiSBE), www.iisbe.org)

Integrated building design

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

Video Presentation



- Pennsylvania’s First Green Building [29 min.]
  - Department of Environmental Protection Southcentral Regional Office Building
  - Location: Pennsylvania, USA; completion: 1999

Green Team Member

How many green team members?

Pennsylvania Department of Environmental Protection
Harrisburg, Pennsylvania

Owner:	New Morgan Municipal Authority	
Project Team:	Architect:	*Kostecky Group*
	Engineer:	*Deepal Wickramasinghe & N.K Gunawardana*
	Contractor:	*909 Partners as GC*
	Consultant:	*Energy Opportunities, Carnegie Mellon University, Penn Energy Project & 21 other*

Building Statistics:

Completion Date:	*May, 1998*
Cost:	*$5.7 M*
Size:	*73,000 gross square feet*
Footprint:	*26,770 square feet*
Construction Type:	*Three story steel frame*
Use Group:	*Business (State Government Office Building)*
Lot Size:	*13.4 acres*
Occupancy:	*240 Employees*

LEED™ 1.0 Certification: BRONZE

Notes from the Project Team: *LEED™ is an invaluable tool for Building Green in Pennsylvania projects which require an integrative design and measuring tool for High Performance Green Buildings.*

❑ Sustainable Sites

- **Site Selection:** *Brownfield (once a quarry then landfill) and within the Harrisburg Area Economic Development Corridor*
- **Resource Protection:** *Leachate & Methane collection for remediation, indigenous plants, & Xeroscaping regenerate natural landscape*

❑ Water Efficiency

- **Water:** *Complies with Energy Policy Act Of 1992, uses water saving fixtures*
- **Storm/Wastewater:** *Xeriscaping techniques help manage stormwater*

❑ Energy and Atmosphere

- **Energy:** *Exceeds ASHRAE/IES Standard 90.1-1989 by 20%*
- **HVAC:** *Raised floor air plenum with individual control of air flow/temperature*
- **Controls/Monitoring:** *Energy and air monitoring systems measure temperature, relative humidity, and CO_2*
- **Power Source:** *Gas-Fired absorption chiller uses water as refrigerant*
- **Lighting:** *Split task indirect ambient with high reflectance ceiling tiles, T-8 lamps and light shelves enhance day lighting*

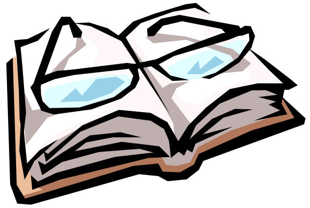
❑ Materials and Resources

- **Structure:** *94% postindustrial Nucor recycled steel frame*
- **Recycled Content:** *25% of materials have substantial recycled content.*

❑ Indoor Environmental Quality

- **Low Emitting Materials:** *Concrete floor with Low-VOC sealant*
- **Furniture:** *Conference room chairs' seat fabric made of wool & plant fiber--toxic free biodegradable. Panel fabric made of100% post-consumer recycled plastic PET.*

Further Reading



- Whole Building Design Guide (WBDG)
  - Sustainable, www.wbdg.org/design/sustainable.php
- Sustainable Building Technical Manual
  - Chapter 5: Sustainable Site Design
  - Chapter 6: Water Issues
  - Chapter 13: Indoor Air Quality
- Integrated Design Process Guide
  - http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/Integrated_Design_GuideENG.pdf