Design and Applied Technology Teaching kit for Senior Secondary Curriculum

Value and Impact

Video: Sustainable Architecture

[Teacher notes]

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Topic 05
Video: Sustainable Architecture

Major teaching areas

Design and Applied Technology

Strand 3 Value and Impact

- Values in Technology and Design

Strand 2 Technology Principles

- Nature of Technology

Interdisciplinary teaching areas

Liberal Studies

- Module 6 Energy Technology and Environment

Physics

- Chapter VIII Energy and Use of Energy

Integrated Sciences

- E1: Energy, Weather and Air Quality

Related teaching areas

Design and Applied Technology

Strand 1 Design and Innovation

- Design and Practice
- Design and Consideration

Learning objectives

- To understand the basic concept of sustainable architecture
- To become familiar with sustainable building technologies
- To demonstrate how sustainable building technologies are applied

Teaching Plan

Lesson	Contents
Lessons 1 **Sustainable Architecture**	• 1.1 Importance of sustainability • 1.2 Applied technologies for sustainable architecture • 1.2.1 Difference between active and passive design • 1.2.2 Choosing the appropriate technology • Exercise Analysis of real-life applications of sustainable design and technology
Appendix **Approaches in Sustainable Architecture**	• Reference on common approaches to sustainable architecture in Hong Kong

These are supplementary teaching notes for the video 'Sustainable Architecture'.

For further reference on statutory regulations, guidelines and technology for sustainable architecture, please see Liberal Studies Topic 7 'VIDEO: Environmentally Friendly Green Buildings' and Science Topic 7 'Energy-saving Approaches in Architecture'.

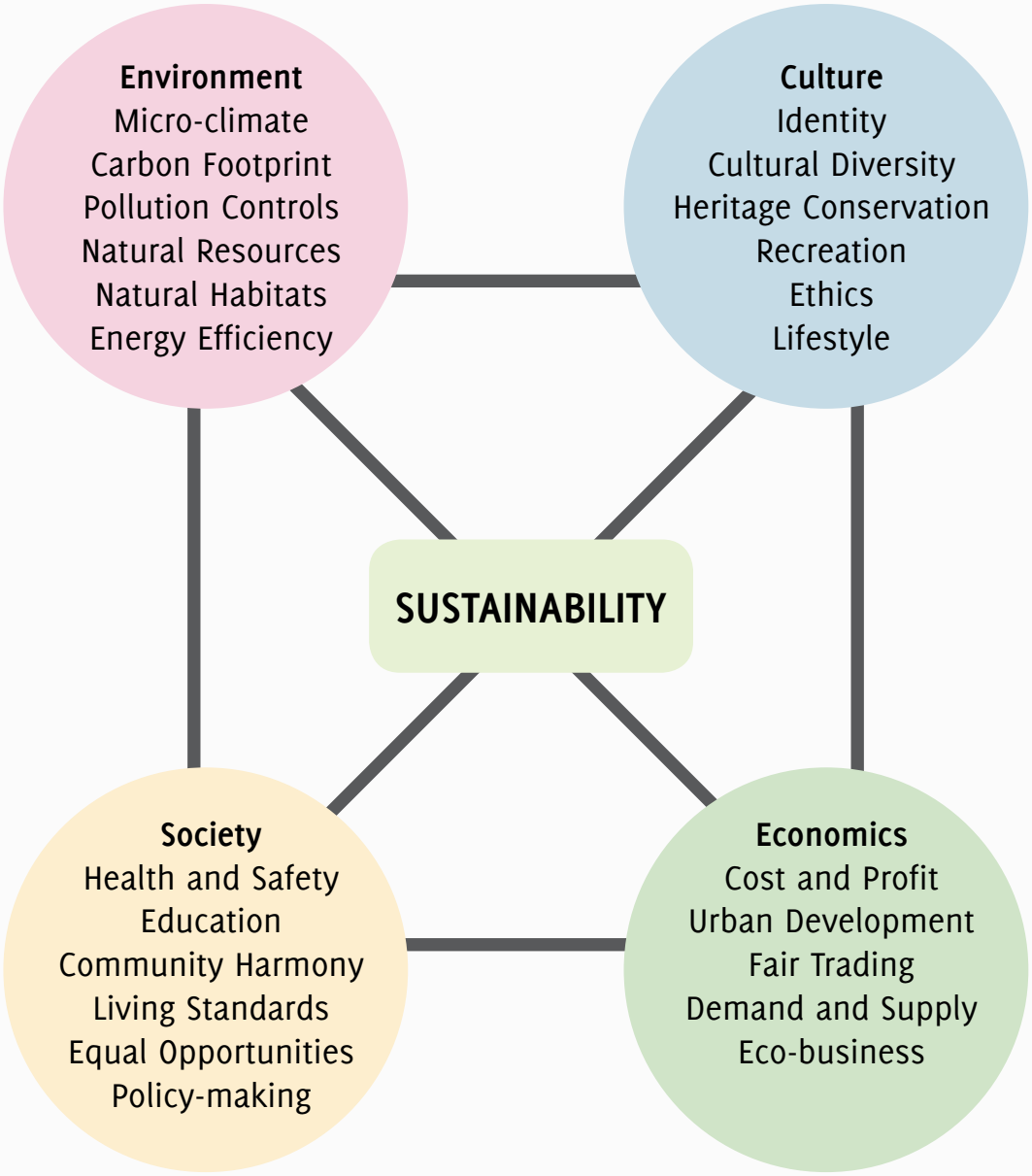
Lesson 1
Sustainable Architecture

Lesson 1 Sustainable Architecture

1.1 What is Sustainability?

As the world's population grows, while pollution problems and climate change become the pressing concerns, more attention has been paid to sustainable development. According to the World Commission on Environment and Development, sustainable development means 'meeting the needs of the present without compromising the ability of future generations to meet their own needs' (Source: World Commission on Environment and Development (WCED), Our Common Future (New York: Oxford University Press, 1987)).

Instead of having a narrow focus on economic growth, a more sustainable approach to develop holistically would be to consider the alternative indicators of well-being to deliver social, economic and environmental goals simultaneously.



▲ Environmental, social, economic and cultural factors all play a role in sustainable development.

1.2 Design and Technology for Sustainable Architecture

Improving indoor comfort, minimizing environmental impacts and reducing energy consumption are the core values of sustainable architecture. A combination of both active and passive building design can increase the sustainability of a building.

1.2.1 Active Design and Passive Design in Sustainable Architecture

Active Design

Active design refers to any automated means of controlling the effect of the outdoor environment (sun, wind) on the indoor environment of a building. Operating active-controlling devices consumes energy, so they may not be optimal choices. Common examples of active design elements are fans and heat pumps.

Passive Design

Passive design attempts to control the indoor environment and enhance occupants' comfort without consuming fuels. This approach is based upon local climate considerations and it involves a high degree of participation from the designers and occupants. The designers must decide which architectural elements and options should be used, while occupants must know when to open or close windows or raise or lower the external shading devices.

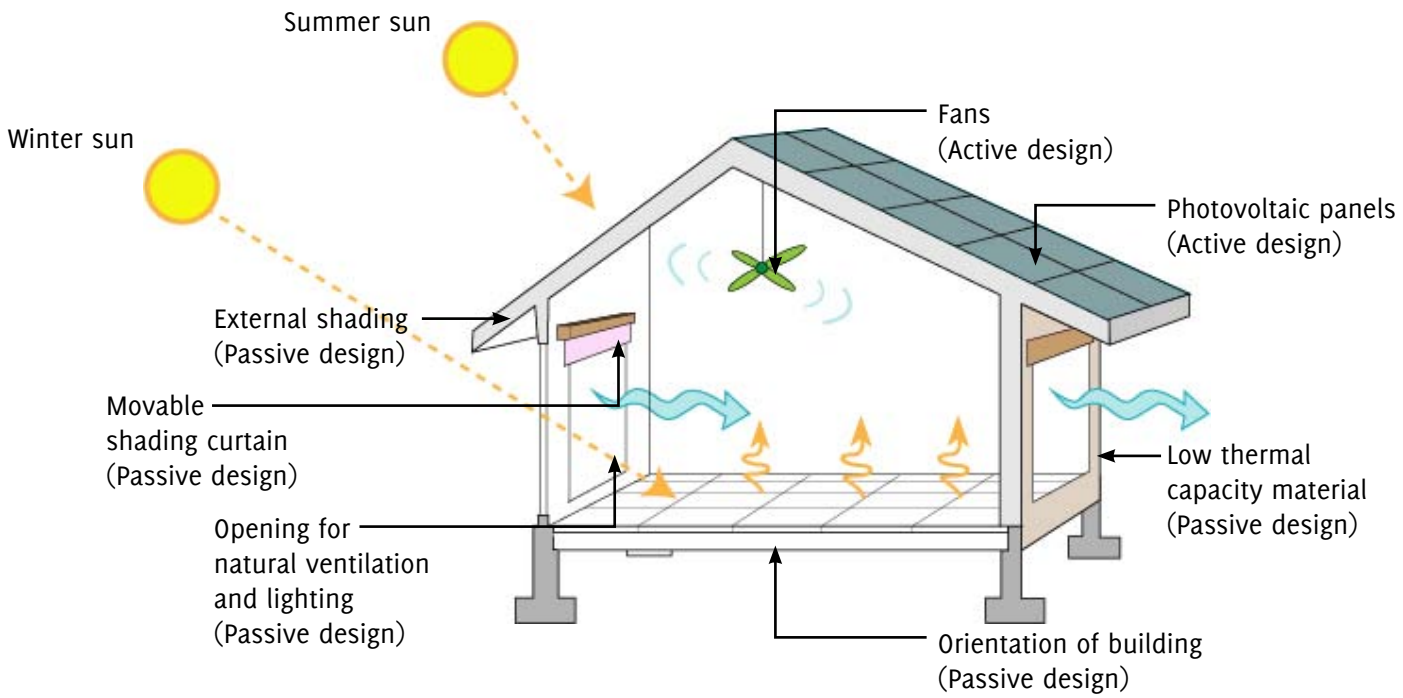
Examples of Passive Design:

- Orientation of buildings to control heat gain and heat loss
- Shape of buildings (plan, section) to control air flow
- Materials to transfer heat between outdoors and indoors
- Maximum use of free and renewable solar energy for heating and lighting
- Maximum use of natural ventilation for cooling
- Use of natural or architectural shading devices to control heat gain
- Making the best use of seasonal climatic changes
- Considering the geographic location of buildings and micro-climate

Teaching Tips
More information about sustainable building design can be found under Science Topic 07: 'VIDEO: Energy-saving Approaches in Architecture', and Science Topic 05 'Noise Control in Architecture'.

[Discussion]

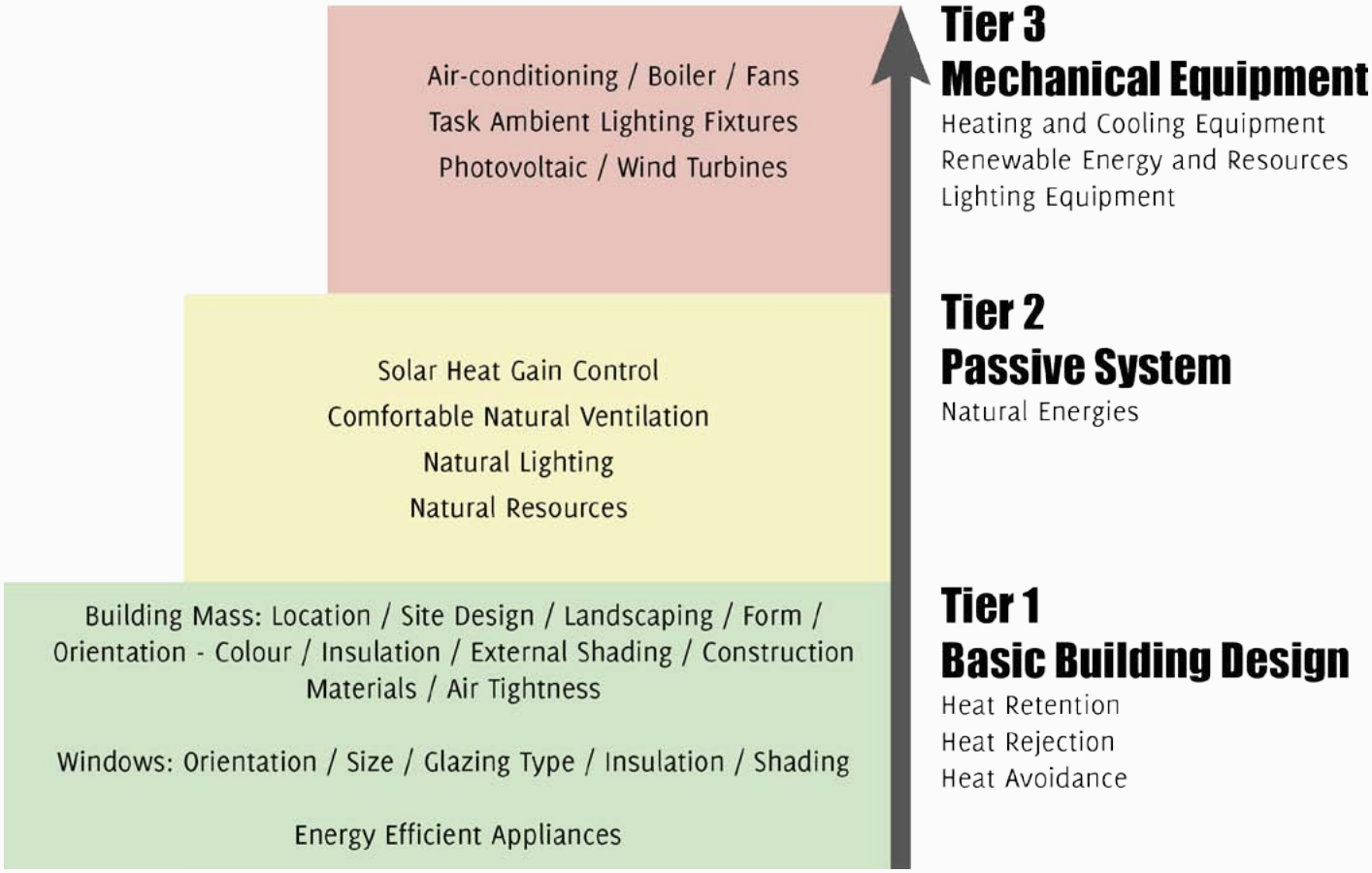
1 What elements of active and passive design can you find in the following diagram?



1.2.2 Choosing the Right Approach to Sustainable Architecture

- Environment: Tailored for local climatic changes
- Environment & Society: Availability of technology and materials
- Economics: Initial installation budget and long-term maintenance costs
- Environment & Economics: Effectiveness of the application
- Society & Culture: Functions and user preferences

Norbert Lechner's 'Heating, Cooling, Lighting: Design Methods for Architects' suggests three tiers for sustainable building design:



▲ Three Tiers for Sustainable Building Design

Teaching Tips
About the importance of having sustainable architecture, please refer to Science Topic 08 'VIDEO: Urban Heat Island'.

[Exercise]

Real-life Applications of Sustainable Design and Technology

In the video, three green buildings are mentioned:

- Zero-Carbon Building,
- Upper Ngau Tau Kok Estate, and
- Diamond Hill Crematorium.

Choose one of the buildings as a case study. Based on your knowledge of active and passive design, and the three tiers for sustainable buildings, identify the sustainable approaches applied. Report to the class and discuss why different approaches are chosen in each project.

Case study: Zero-Carbon Building/ Upper Ngau Tau Kok Estate / Diamond Hill Crematorium		
Assessment Aspects	**Applied Design and Technology**	**Active/ Passive Design**
Site Aspects		
Material Aspects		
Energy Use		
Indoor Environmental Quality	To be completed by students	
Ventilation Systems		
Greening and Landscape		

Suggest Answer

Real-life Applications of Sustainable Design and Technology

1. **Zero-Carbon Building**

Site Aspects
- Micro-climate (reducing UHI effect)

Energy Use
- Carbon neutral (offset of operating energy consumed from the grid by on-site renewable energy generation with grid-feed-in on an annual basis)
- Energy plus (generating on-site renewable energy more than operation needs, from photovoltaic panels)
- Waste to energy (a biodiesel tri-generation system)

Greening and Landscape
- Urban Native Woodland
- over 60% of greenery

Material and Technology Aspects
- Experimental and evaluation (adoption of the state-of-the-art design and technologies)
- Evolution (flexible design to cater for the fast-evolving low carbon and eco-building technologies and changing needs)

(Source: Hong Kong Construction Industry Council)

2. **Upper Ngau Tau Kok Estate**

Site Aspects
- Building Information Modeling (BIM)
- Computational Fluid Dynamics (CFD)

Energy Use
- Natural lighting
- Natural ventilation

Material Aspects
- Light-painted wall finishes

Indoor Environmental Quality
- Dispersal of air pollutants

Greening and Landscape
- Trees and green sloped leisure space

3. **Diamond Hill Crematorium**

Site Aspects
- Minimizing land damage
- Treatment before waste gas emission

Energy Use
- Lotus ponds reducing surface heat gain and air-conditioning load
- Green roof and walls

Teaching Tips

Teachers can also bring students to Wetland Park for field trip. Information can be found in Science Topic 09 'VISIT: Hong Kong Wetland Park - Human impact, Pollution control, Sustainability and Energy efficiency.'

Comparison of Applied Approaches in Different Projects

1. Zero-Carbon Building is the earliest model of carbon-free architecture in Hong Kong, so it received the most funding and scientific support regarding green materials and technology. It showcases how zero-carbon buildings can operate, and how they can contribute to society.

2. Upper Ngau Tau Kok Estate of is a public estate built by the Housing Authority. It uses many low-budget passive design elements to provide free sources of lighting and ventilation. It also includes many green leisure spaces in order to provide a healthy living environment for the occupants.

3. The main concern in the Diamond Hill Crematorium is the treatment of waste air after cremation. The project adopts fewer user-oriented approaches, compared with the other two projects. It creates a pleasant indoor and outdoor environment to the users without increasing the energy load of the complex.

Summary

1. Sustainable development should consider environmental, social, cultural and economic aspects.
2. Sustainable design and technology in architecture includes active design and passive design. A combination of both can reduce impacts to the environment and provide comfort to the users.
3. Sustainable approaches to design might include:
    - Site planning and management
    - Water use
    - Material use
    - Energy use
    - Indoor environmental quality
    - Greening work

Key words

Sustainability
Active design
Passive design
Micro-climate
Energy efficiency

Further reading

1. 'Ngau Tau Kok: From Lower to Upper Ngau Tau Kok Estate', Hong Kong Housing Authority http://www.housingauthority.gov.hk/tc/common/pdf/about-us/publications-and-statistics/UNTK.pdf
2. 'Green Estates', Hong Kong Housing Authority http://www.housingauthority.gov.hk/hdw/en/aboutus/events/greenestate/sec3.html
3. 'Sustainable Architecture', Faculty of Architecture, The University of Hong Kong http://www.arch.hku.hk/research/BEER/sustain.html
4. 'Green Building', Government of Hong Kong http://www.gov.hk/en/residents/environment/sustainable/buildings.htm
5. 'Climate Change of Building', Environmental Protection Department http://www.epd.gov.hk/epd/english/climate_change/bldg.html
6. 'Sustainable Design Part Three: The Basic Principles of Passive Design' by Terri Boake, University of Waterloo http://www.slideshare.net/tboake/sustainable-design-part-three-the-basic-principles-of-passive-design
7. Lechner, Norbert. Heating, Cooling, Lighting: Design Methods for Architects. New York: John Wiley & Sons, 2000.
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9. World Commission on Environment and Development (WCED). Our Common Future. New York: Oxford University Press, 1987.
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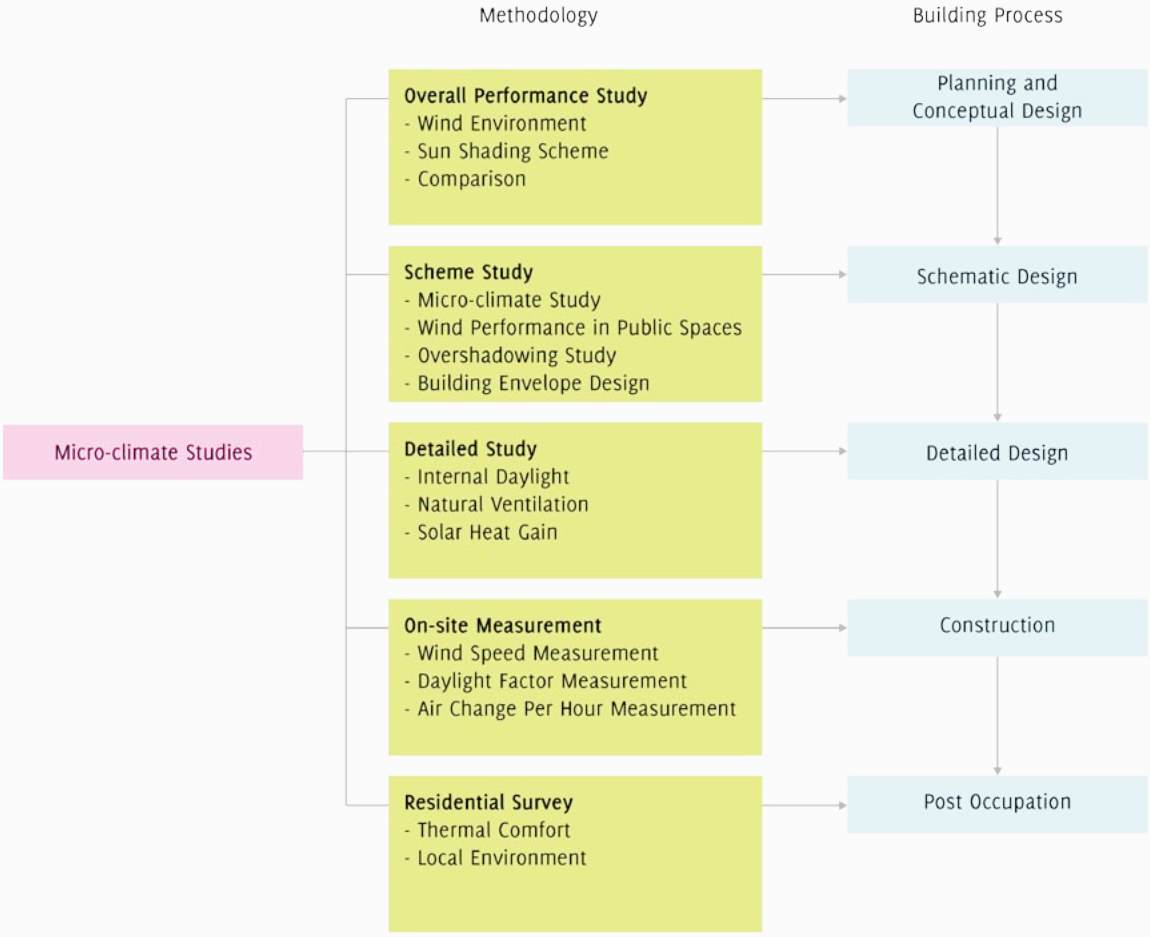
Appendix:
Approaches in Sustainable Architecture

I) Micro-climate Studies

Micro-climate studies are used to evaluate environmental performance and to enhance design, orientation and disposition of architecture and the surrounding environment.

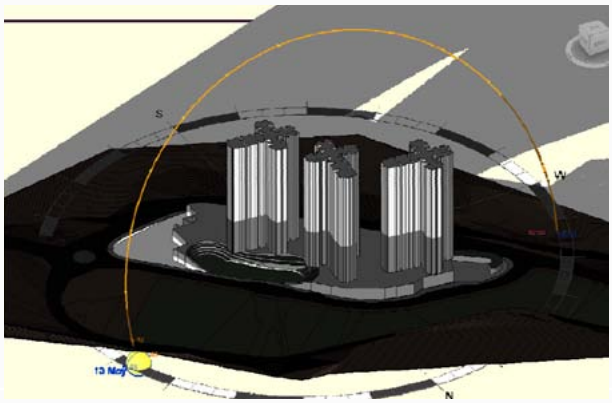
Flow chart of Micro-climate Studies

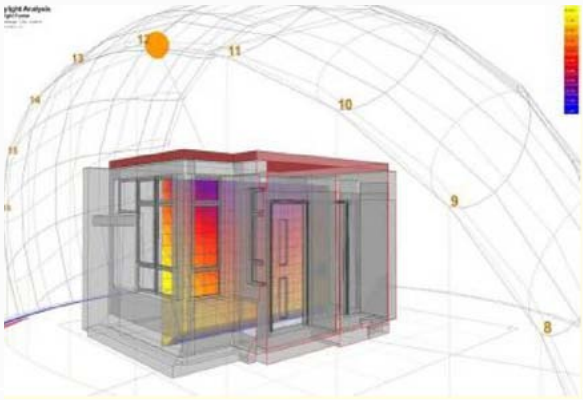


i.i) Building Information Modelling (BIM) – Towards 3-D Modelling

3-D Building Information Modelling takes advantage of computer technology to:

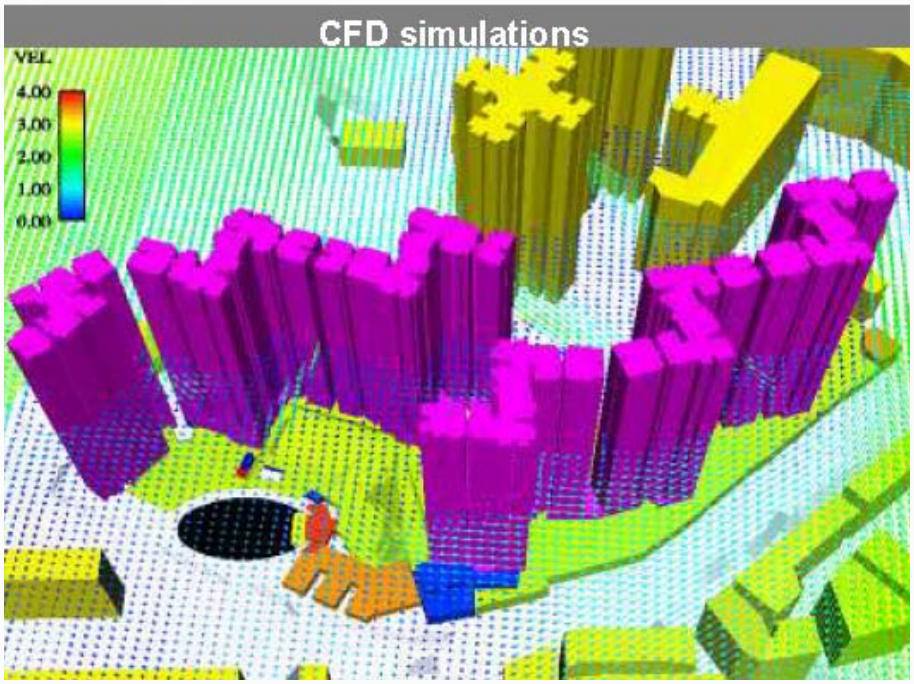
- Provide building design in three dimensions. Combine design drawings, specifications, building services and structure in one program.
- Save time, save paper and save waste of work and materials.
- Assist in design, tender, construction, operation and maintenance





i.ii) Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) technology is an approach to studying site micro-climates. Since 2004 it has been successfully used by the Hong Kong Housing Authority to test all newly designed public housing estates, optimizing the orientation and disposition of the blocks. Date from these studies can benefit a construction project in multiple stages, from planning and conceptual design to post-occupation building management.

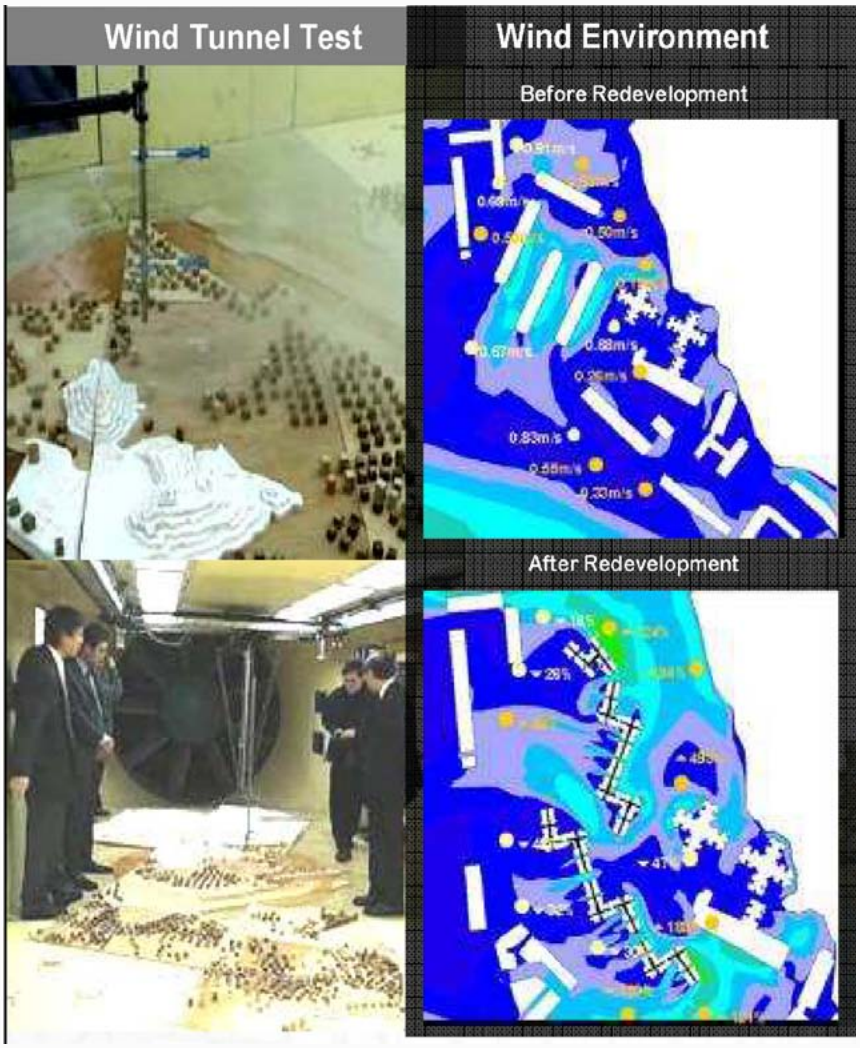


Teaching Tips
More information about public housing development can be found under Liber Studies Topic 09 'Public Housing — improvement in quality of life'.

◀ A panel showing the result of computational fluid dynamics technology in the Upper Ngau Tau Kok Estate.

i.iii) Air Ventilation Assessments (AVA)

A sustainable design process should study whether new buildings would pose any restriction on air flow.



◀ Example of Air Ventilation Assessments of the Upper Ngau Tau Kok Estate.

II) Building Envelope Design

ii.i) Window Design

In order to reduce heat gain, external window shading should be extended while window glazing area should be reduced.

The type of glass used in windows affects the amount of solar heat transfer to the interior. Low-E glass and tinted glass are used in west-facing windows to reduce heat gain.

Low-E glazing

Low-E glass (E = thermal emissivity) is coated with metal oxide to reduce the amount of solar radiation that enters the interior. Most of the radiant heat of the sun is reflected, resulting in good heat insulation, but visible light can still pass through the glass.

Double-glazing

Double-glazed windows provide horizontally offset openings that allow natural ventilation while preventing direct propagation of traffic noise. The narrow gap between the double window panes dissipates sound energy and lowers noise levels to improve the indoor living environment. Air trapped between the two glazing also acts as a good heat insulating layer between outdoors and indoors.

Teaching Tips

More information about low-E double glazing can be found under Science Topic 06 'Calculation and Application of Overall Thermal Transfer Value (OTTV) and U-value'.

ii.ii) Wall Finishes

Heat can be transferred through and stored within opaque exterior walls. Use of finishes of high reflectance and low thermal capacity can reduce the effect. Generally, light-coloured finishing materials absorb less solar heat radiation than darker materials.

III) Ventilation Systems

iii.i) Hybrid Ventilation System

A sensor system is installed to operate automatic windows to encourage natural ventilation instead of air-conditioning. There are three modes in the system:

- Air-Conditioning Mode: Cool air from central air conditioner with minimum fresh air. Operates in hot seasons when outdoor conditions are not suitable for free cooling and natural ventilation.
- Free Cooling Mode: Partial mechanical ventilation with fresh air intake from outdoors. Minimal chilled water supplied. Operates at moderate climatic periods.
- Natural Ventilation Mode: Uses outdoor fresh air to condition indoor areas. Fresh air intake occurs by means of the stack effect. Operates at moderate climatic periods when ambient temperature and humidity satisfy design conditions and meet indoor thermal comfort criteria.

iii.ii) Wind Corridor

A wind corridor between building blocks guides the prevailing winds of the area to provide cooling and air pollutant dispersal. This can prevent the 'wall effect' and help to alleviate Urban Heat Island effect.

Building blocks of the Upper Ngau Tau Kok Estate align to create a 30-meter wide wind corridor to guide the summer prevailing wind. © Hong Kong Housing Authority

IV) Water Use

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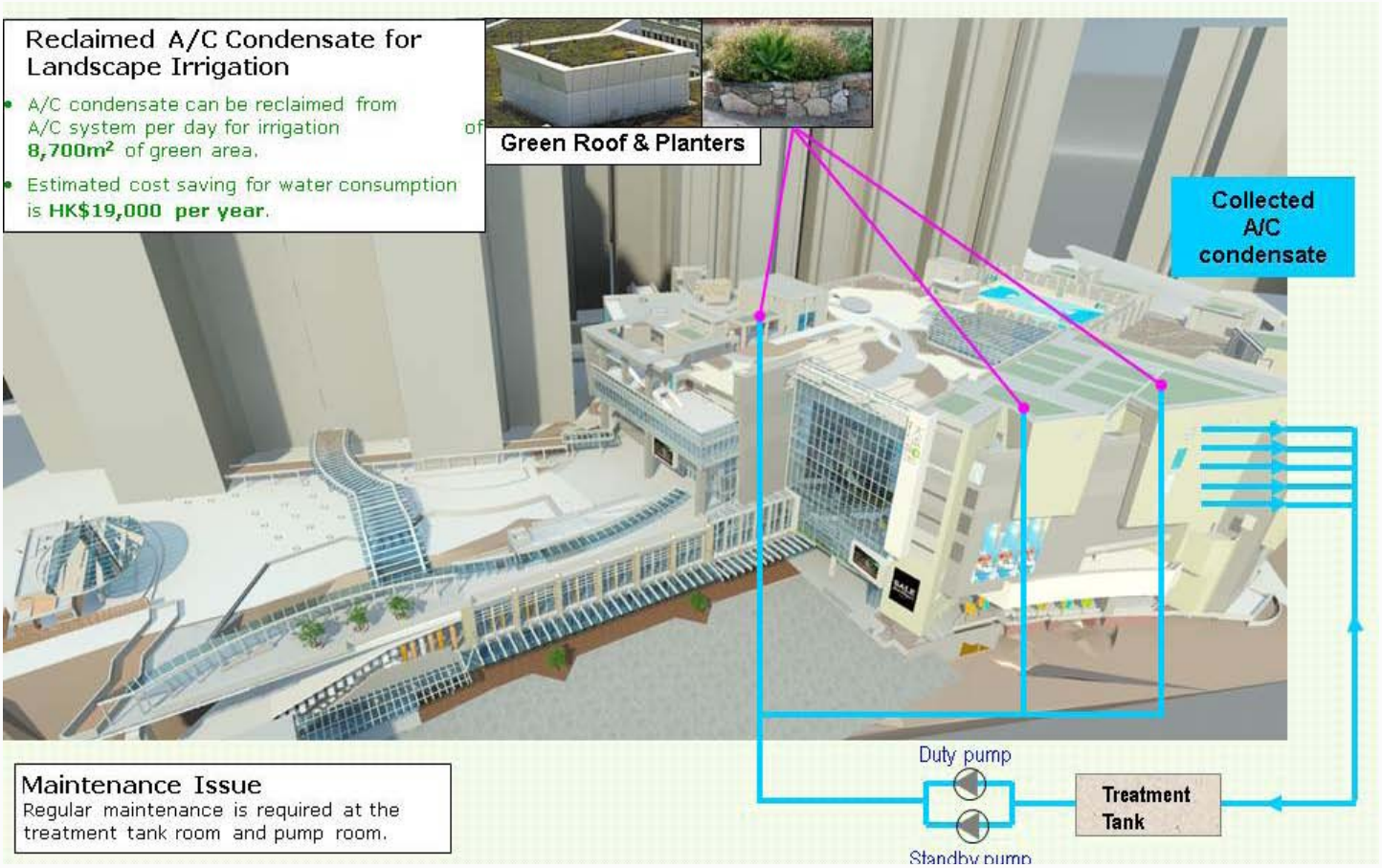
In the shopping arcade Domain at Yau Tong, reclaimed water from air conditioner condensate is sufficient for the irrigation of all planter areas. This reduces water consumption and waste. The image below indicates the connection between air-conditioners, treatment tank, pumps and landscape elements.



Reclaimed A/C Condensate for landscape irrigation in the shopping arcade Domain at Yau Tong

Teaching Tips
More information about sustainable building design can be found under Design and Applied Technology Topic 07: 'VIDEO: Sustainable Architecture'.

V) Material Use

v.i) Life Cycle Assessment and Life Cycle Costing methods

Life cycle assessment focuses on evaluating a product's impact on the environment through all of its 'life stages' including raw material extraction, materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling. It has also been called a 'cradle-to-grave' approach. Life cycle costing methods are similar, but they also calculate the financial costs of the product at various stages.

v.ii) Use of Environmentally Friendly Materials

New buildings make use of many environmentally friendly materials like Medium Density Fibreboard (a recycled timber product) and timber from sustainable sources. Materials that embody high levels of energy are to be avoided.

In the shopping arcade Domain at Yau Tong, Medium Density Fibre (MDF) board panel is used for the spandrels in the atrium. MDF is a recycled timber product. © Hong Kong Housing Authority

Sustainable design relies as much as possible on timber from sustainable and responsibly managed sources, such as sources certified by the Forest Stewardship Council (FSC). The FSC is an independent, non-governmental, not for profit organization established to promote the responsible management of the world's forests. It provides a labelling system that certifies wood products from environmentally and socially responsible sources.

VI) Renewable Energy

vi.i) Wind Turbines

Wind turbines are an excellent source of renewable energy. They can be integrated into ventilation bays to take advantage of prevailing winds.

Sau Mau Ping Estate uses wind turbines to generate electricity for public lighting.

vi.ii) Adoption of Grid-connected Photovoltaic Panel System

Several photovoltaic panels such as mono-crystalline silicon, poly-crystalline silicon and amorphous silicon thin film photovoltaic modules, have been tested in Hong Kong. These panels convert solar energy into electrical energy for public facilities.

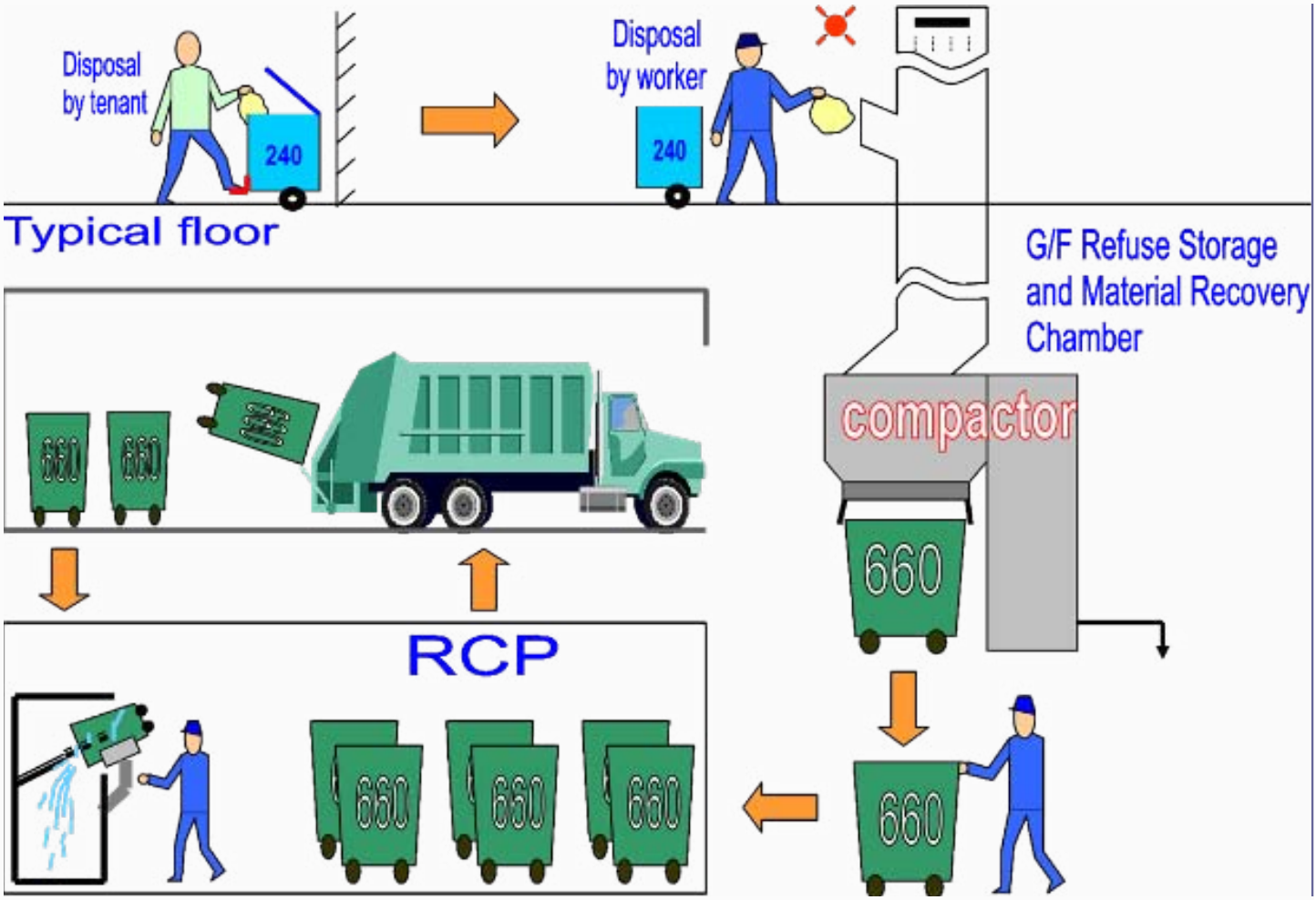
Mono-crystalline silicon PV at Lam Tin Estate Phases 7 & 8 © Hong Kong Housing Authority

VII) Waste Management

A housing estate generates a huge volume of rubbish every day. New technology can help reduce the energy consumption needed for handling waste and simplify the workload of sorting out recyclable waste.

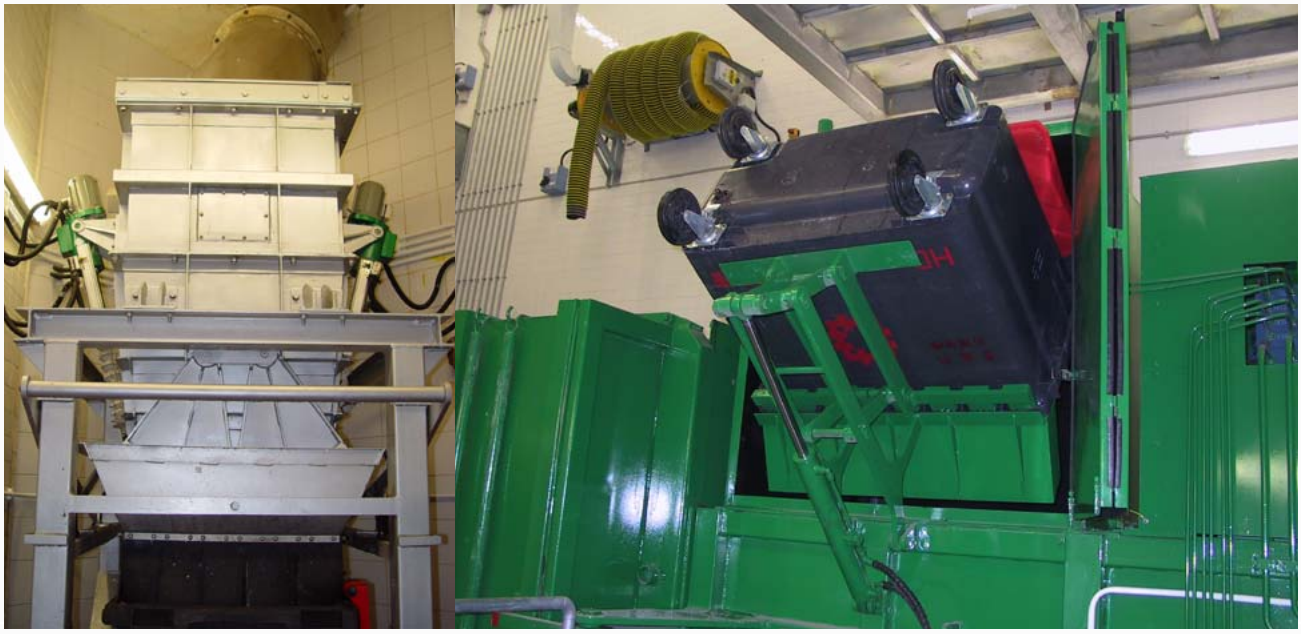
Refuse Handling System

A Central Compactor System can be installed within a central refuse collection point or a separate, small-scale Distributed Compactor System can be used.



© Hong Kong Housing Authority

The above diagram illustrates the mechanism of a Central Compactor System. Solid wastes are concentrated and compressed before loading onto garbage trucks to reduce the energy needed for transportation. Reusable materials can be recovered for later recycling. Photographs below show a typical compactor.



© Hong Kong Housing Authority

VIII) Greening Work

Green or landscaped areas should be increased as much as possible, with the goal of greening 30% of the total site area. Grass driveways, vertical green walls and green roofs are three ways to integrate green surfaces into the architecture.


1


2


3

Greening in public housing:

1. At least one tree is planted for every 15 flats
2. Vertical greening
3. Green roof

IX) Benchmarking

New building projects undertaken by the Housing Authority are required to check carbon emission estimation performance against a set of benchmarks for sustainable building performance. The benchmarks include:

- England: Building Research Establishment Environmental Assessment Method (BREEAM)
- U.S.A.: Leadership in Energy and Environmental Design (LEED)
- China: Green Building Assessment Standards, Gold Star Assessment
- Hong Kong: Building Environmental Assessment Method (BEAM Plus)

Teaching Tips

More information about benchmarking can be found under Liberal Studies Topic 07: 'VIDEO: Green Buildings'.