



# Green Roofs and Vertical Greening in Hong Kong

## 香港綠化屋頂和垂直綠化的研究和應用



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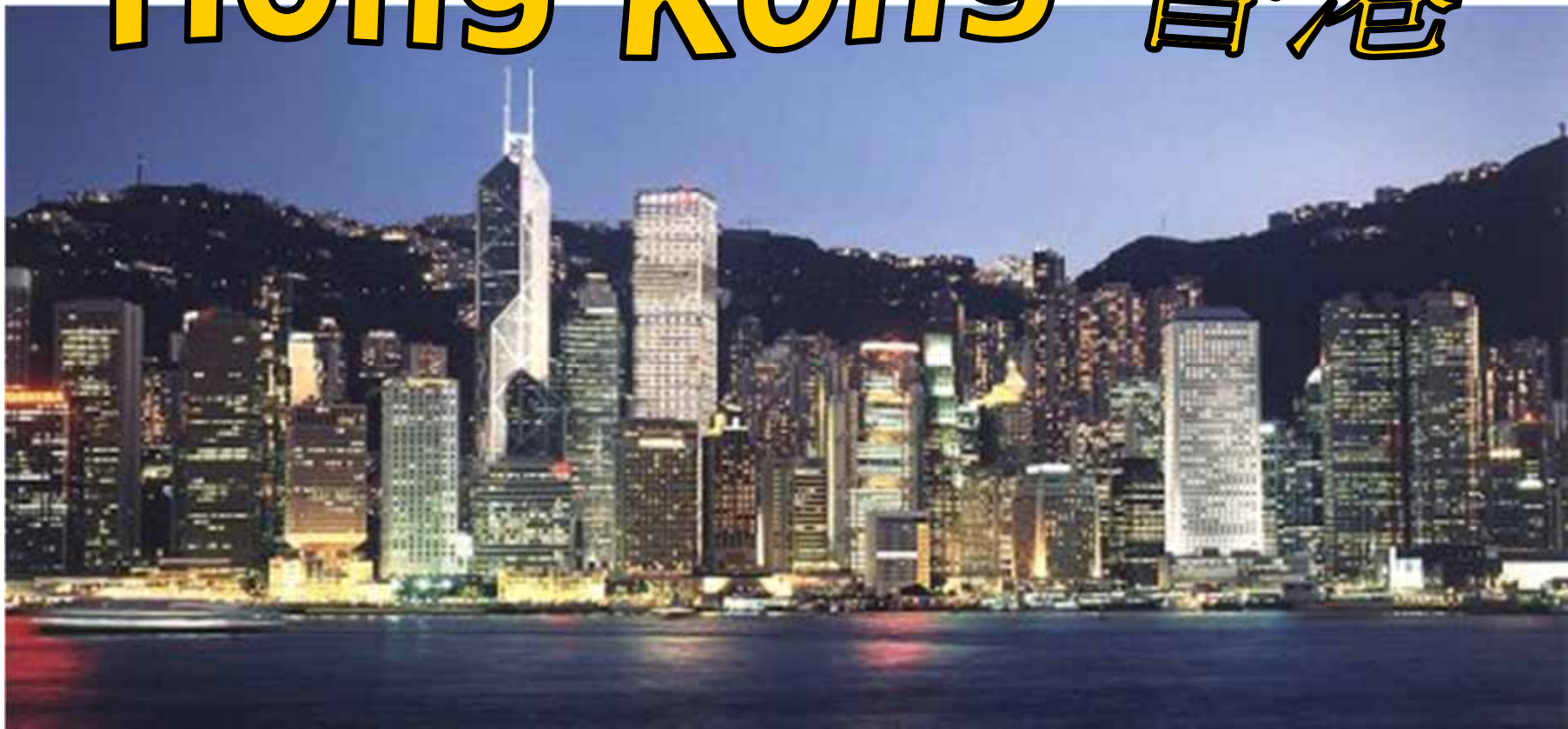
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# HONG KONG 香港





# Introduction 引言

- Hong Kong Special Administrative Region (HKSAR) 香港特別行政區



- Land area 土地面積: 1,104 km<sup>2</sup>
- Population 人口: 7.18 millions
- Population density 人口密度: 6,504 persons/ km<sup>2</sup>
- High urban density to meet population growth  
高建築密度應付人口增加



- Urban heat island and lack of greenery space  
城市熱島和缺乏綠化空間的問題日益嚴重





# Introduction 引言

- Promote green roofs and vertical greening to achieve urban sustainability 推展綠化屋頂和垂直綠化，實現城市可持續性
- Common types of roof greening: podium gardens and sky gardens 屋頂綠化的常見類型：平台花園和空中花園
- New greening techniques: 新的綠化技術
  - Extensive green roofs 粗放型屋頂綠化
  - Living walls & green facades 活生牆和綠化牆



# A residential podium garden 住宅平台花園



(Photos taken by Dr Sam C M Hui)

# Podium garden (Kowloon Station) 平台花園 (九龍站)



(Photos taken by Dr Sam C M Hui)

# Sky gardens in commercial buildings 在商業大廈的空中花園



(Kowloon Commerce Centre 九龍貿易中心)



(HSBC Building Mongkok 旺角匯豐大廈)





# Introduction 引言

- Our research 我們的研究\*
  - Started in 2002 從2002年開始
    - 1. Assess the potential & impacts of urban greening 評估城市綠化的潛在影響
    - 2. Develop practical guidelines & information 制定切實可行的指引及信息
    - 3. Evaluate building greening policy 評估建築綠化政策
    - 4. Promote education & technology development 促進教育和科技發展





# Introduction 引言

- Examples of previous studies: 以前研究例子
  - Energy and environmental performance of green roofs and living walls 綠化屋頂和活生牆的節能和環保性能
  - Design and assessment of modular green roof systems 模塊化屋頂綠化系統的設計與評估
  - Life cycle analysis of green roof urban farming 屋頂綠化都市農業的生命週期分析
  - Feasibility study of green noise barriers 綠化隔音屏障的可行性研究

# Green roof research at a construction site office in Hong Kong 在香港建築地盤辦事處的屋頂綠化研究 (2002-2006)



Green site office



Modular design

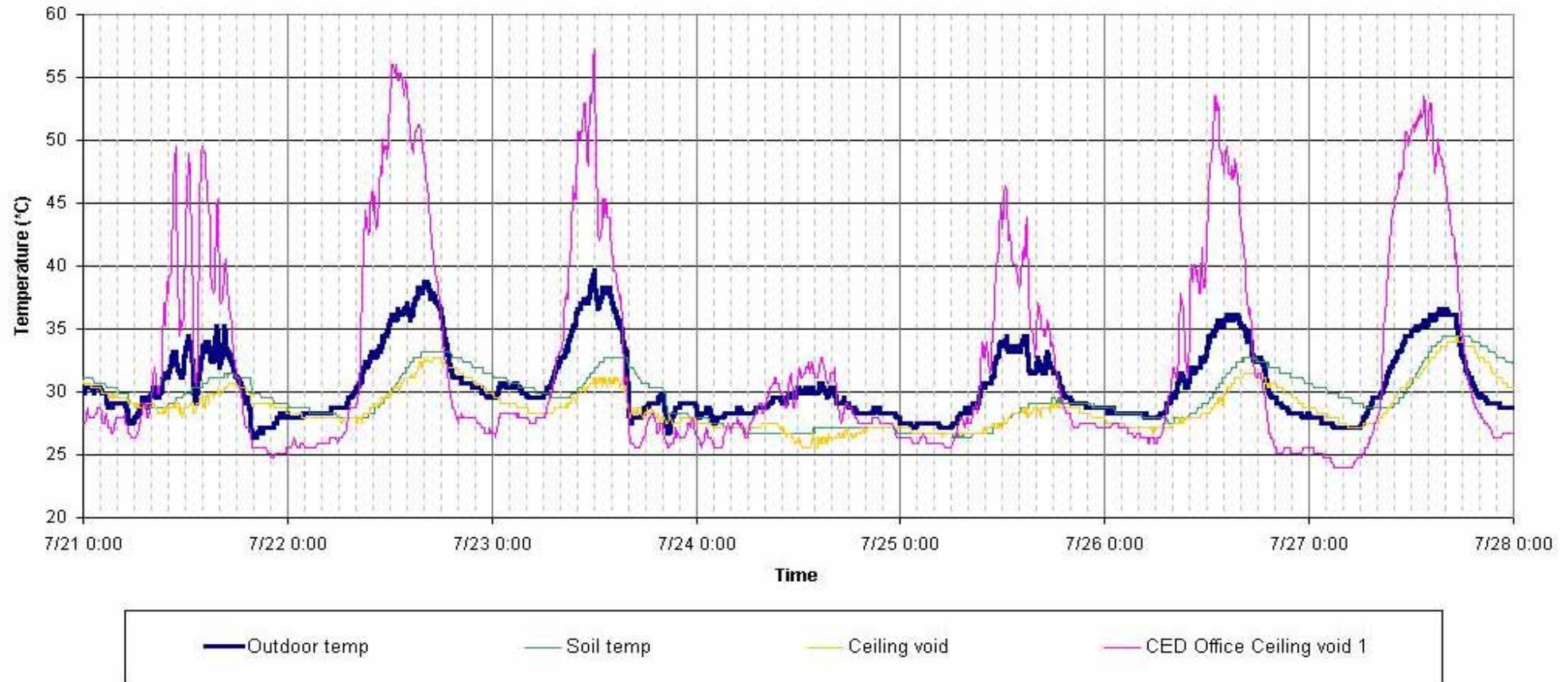


Green site office and typical site office

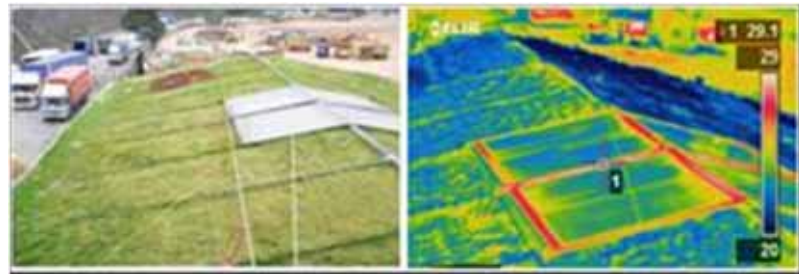


Water sprinkler

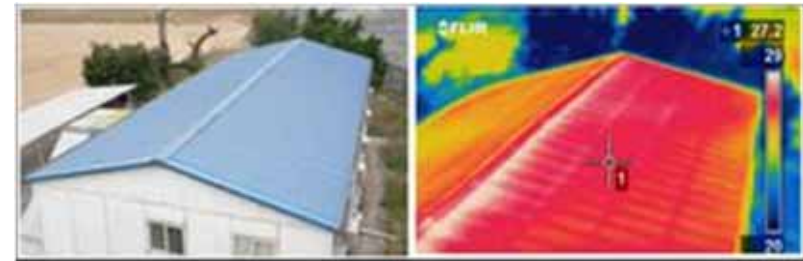
# Green roof research at a construction site office in Hong Kong 在香港建築地盤辦事處的屋頂綠化研究



## Infrared pictures:



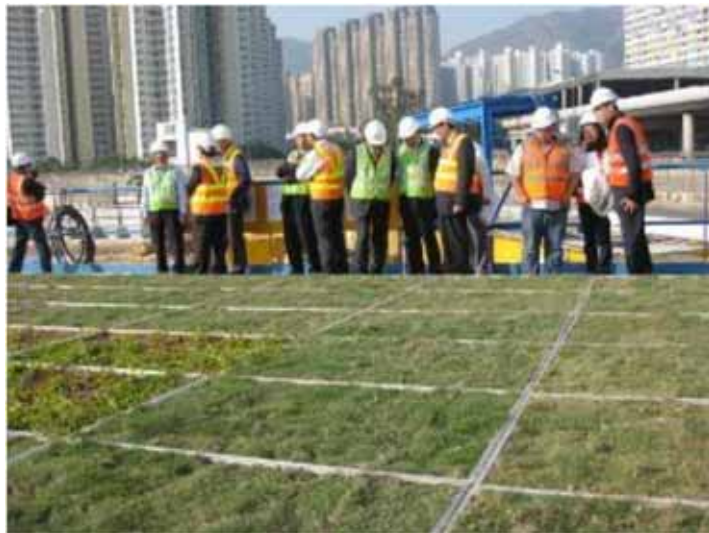
Green roof



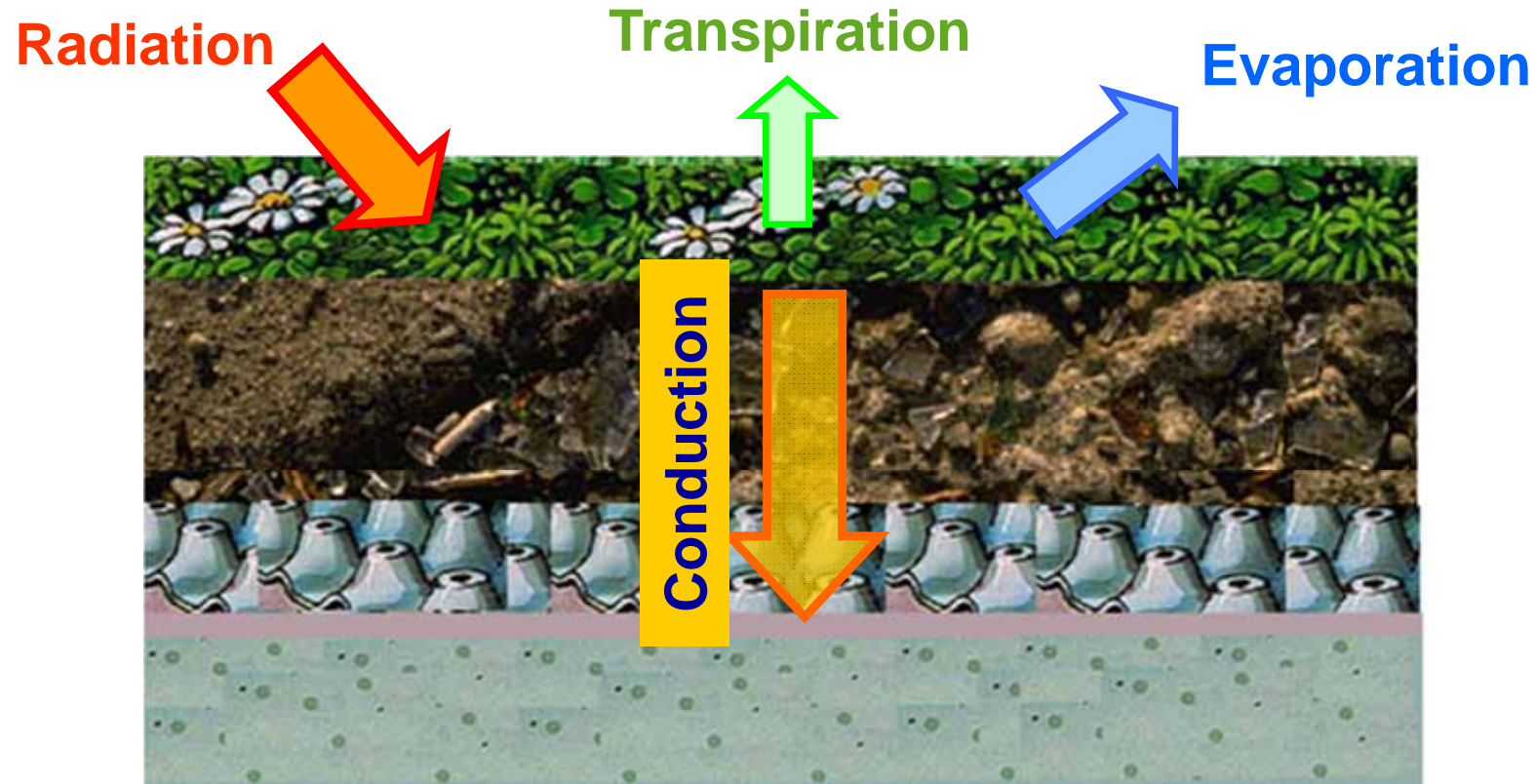
Conventional roof

# Green roof and vertical green for construction site offices

## 在建築地盤辦事處的屋頂綠化和垂直綠化的應用



# Thermal modelling of green roofs 綠化屋頂的導熱建模



Radiation:  $R_n = R \exp(-k_s LAI)$

Evapo-transpiration:  $q'' = -2LAI \frac{\rho C_p}{\gamma(r_e + r_i)} \left( \frac{wR T}{h_m} \right)$

Conduction:  $q'' = (T_{s1} - T_{s2}) / R_{total}$

# Study of modular green roof systems (2007-2008)

## 模塊化屋頂綠化系統的研究



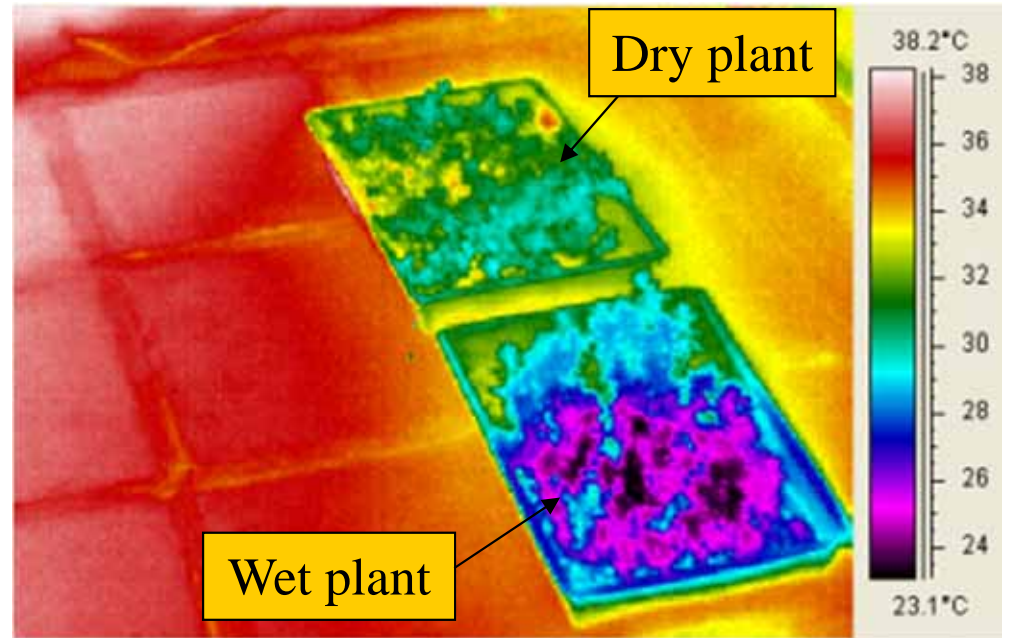
Aluminum trays



Wooden boxes



Plastic trays



Plastic trays (infrared photo)

# Green roof systems from Germany (left) and Japan (right)

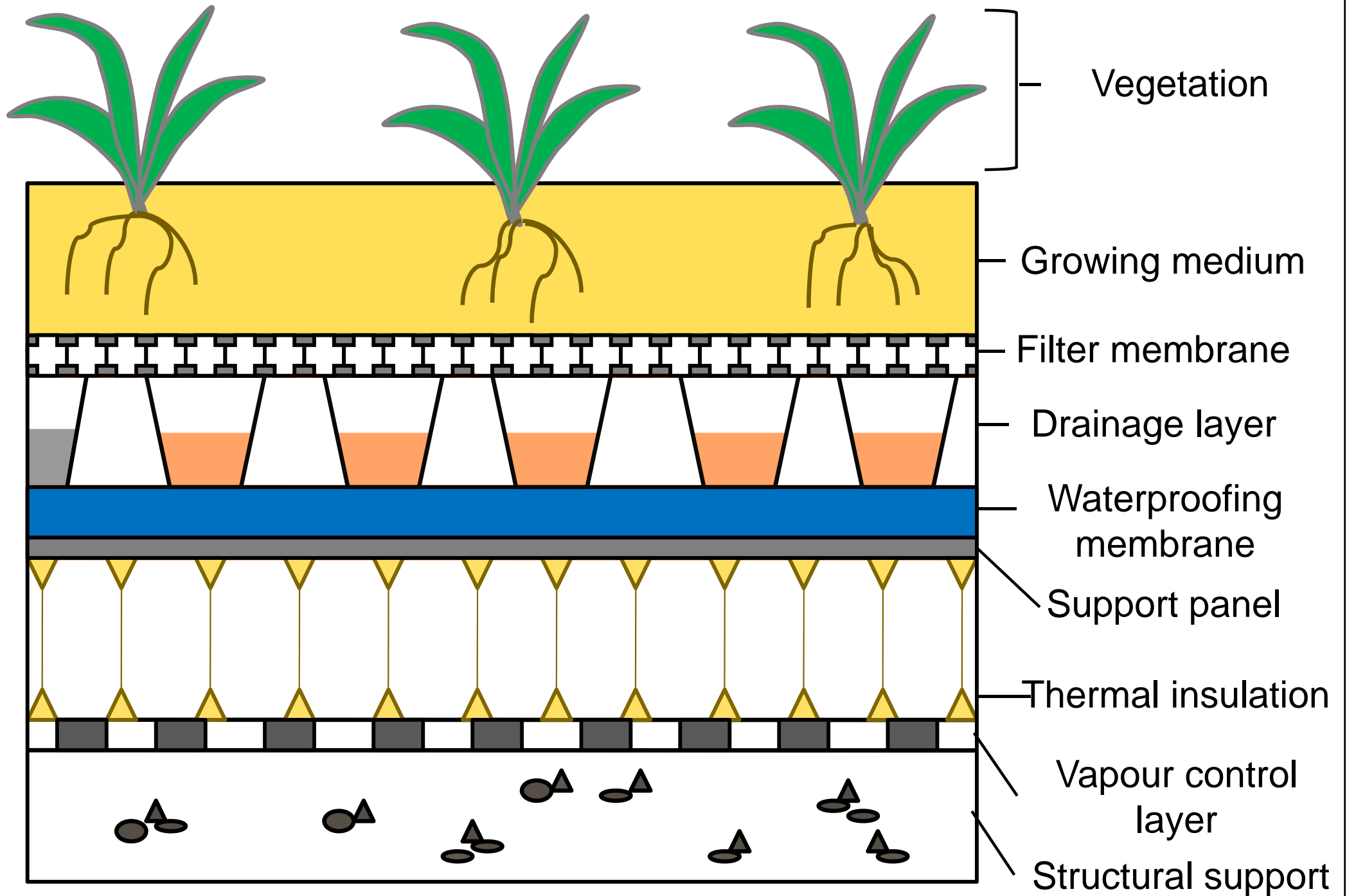
綠化屋頂系統：德國（左）和日本（右）





# Typical structure of extensive green roof

## 粗放型屋頂綠化的典型結構



# Green noise barrier 綠色隔音屏障



(Source: Highway Department, HK)



# Introduction 引言

- Recent research studies 最近完成的研究：
  - Technical guidelines for green roof systems (done) 屋頂綠化系統的技術指南（已經出版）
  - Integration of green roof and solar energy systems 綠化屋頂和太陽能系統的整合
  - Evaluate indoor living walls 室內活生牆的評估
  - Thermal regulation performance of living walls 活生牆的熱調節性能
  - Year-round energy performance of vertical greening systems 垂直綠化系統的全年節能性能

# Guidelines for the design and application of green roof systems



Hui, S. C. M., 2013. *Guidelines for the Design and Application of Green Roof Systems*, Chartered Institution of Building Services Engineers, London. (ISBN 978 1 906846 40 4)

屋頂綠化系統的設計與應用指引

1. Introduction 引言
2. Scope 範圍
3. Definitions 定義
4. Planning Requirements 規劃要求
5. Design Considerations 設計注意事項
6. Construction Methods 施工方法
7. Maintenance Issues 維護問題
8. Project Management 項目管理



# Integration of green roof and solar energy systems

## 綠化屋頂和太陽能系統的整合



(Photos taken by Dr Sam C M Hui)

# Indoor green wall 室內綠化牆



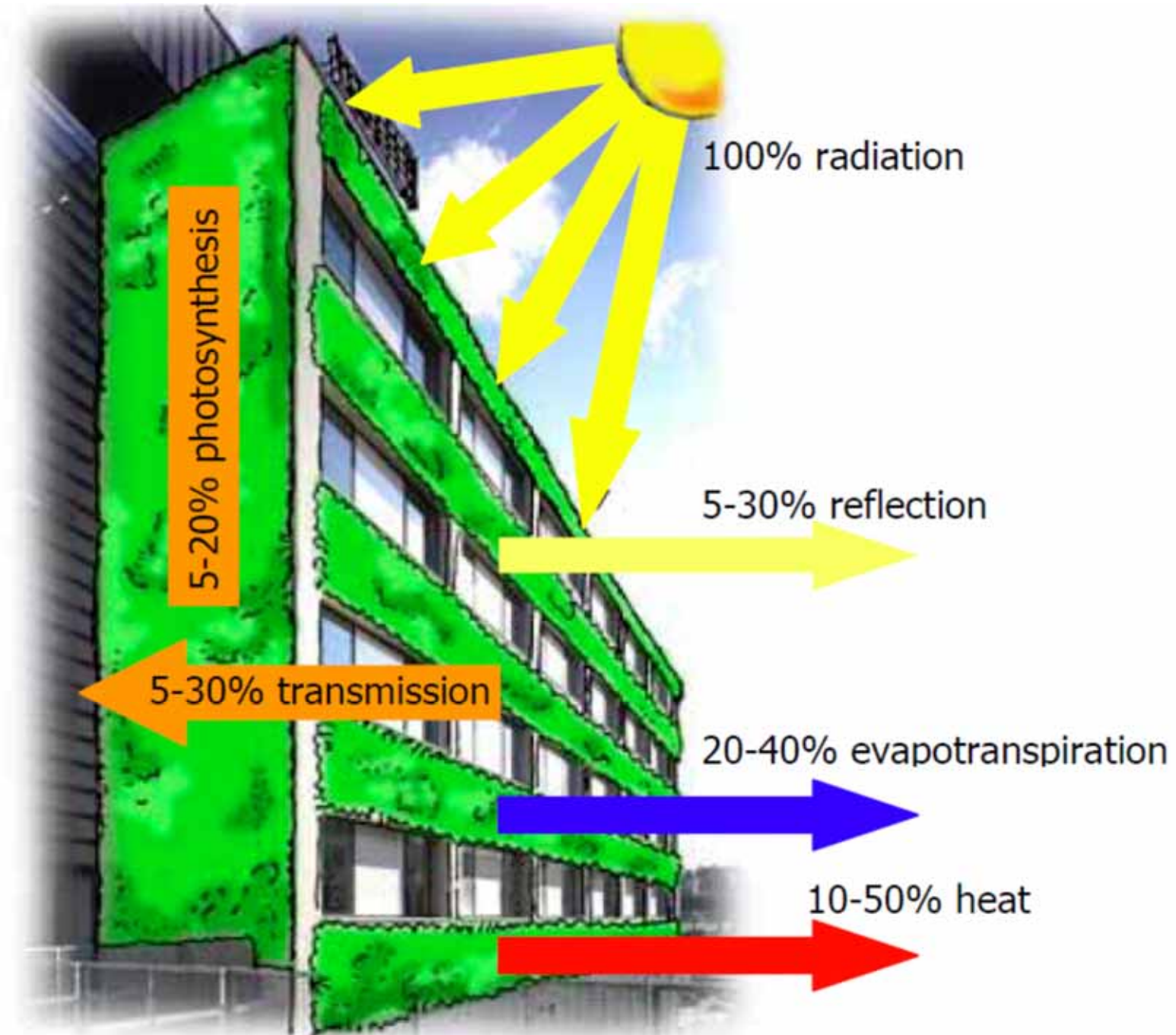
(International Commerce Centre 國際貿易中心)

(Photos taken by Dr Sam C M Hui)

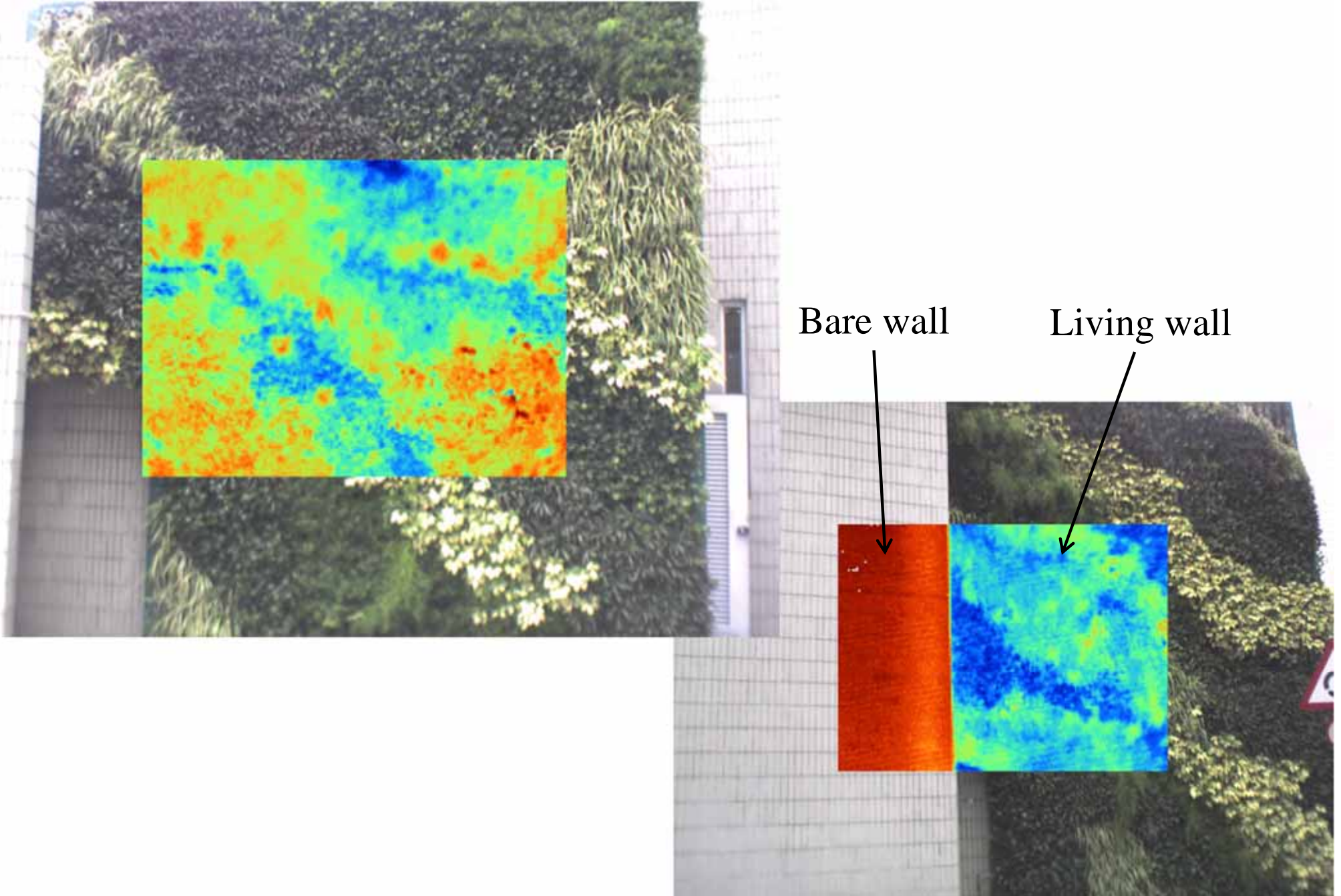


(International Finance Centre 國際金融中心)

# Energy balance for a green wall 綠牆的能量平衡



# Infra-red photos of vertical greening 垂直綠化的紅外線照片







# Introduction 引言

- Current studies 目前的研究:
  - Technical guidelines for vertical greening systems 垂直綠化系統的技術指南
  - Evapotranspiration analysis of vertical greening systems 垂直綠化系統的蒸散量分析
  - Double skin façade with vegetation plants 雙層幕牆加植被植物
  - HK green roof and green building policy 香港的綠化屋頂與綠色建築政策

# Potential benefits 潛在的好處



- Green roofs & vertical greening 綠化屋頂和垂直綠化
  - Building integrated vegetation 建築綜合性植被
  - Urban cityscape 城市景觀
  - Green infrastructure 綠色基礎建設
- Possible benefits: 可能的好處
  - 1. Environmental 環境的
  - 2. Economic 經濟的
  - 3. Social 社會的



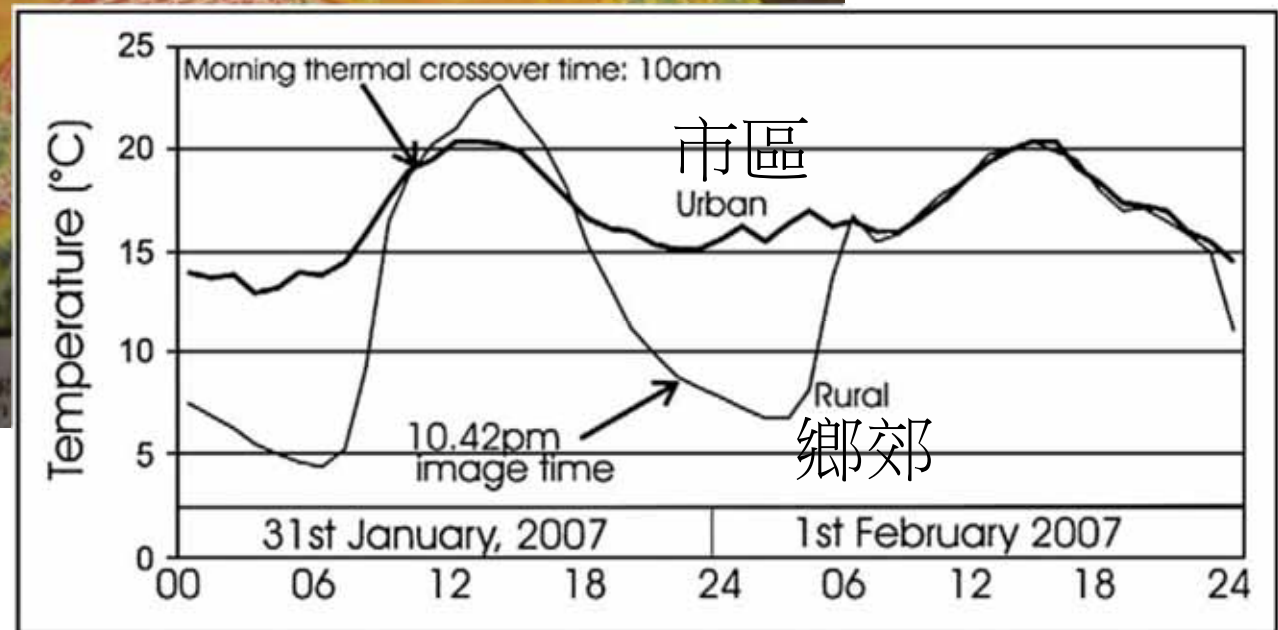
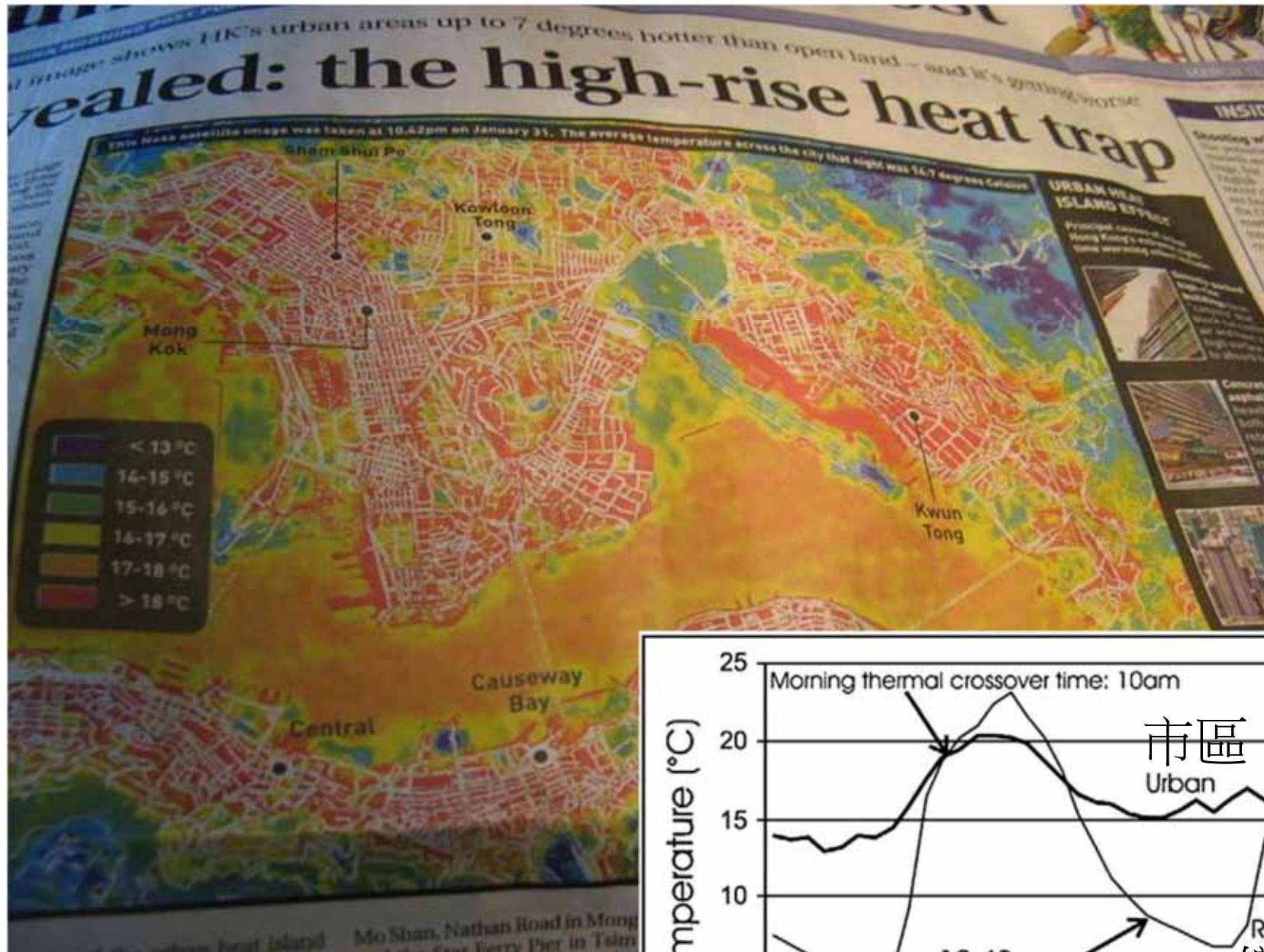
# Potential benefits 潛在的好處



- 1. Environmental benefits: 環境的好處
  - - Mitigate urban heat island 緩解城市熱島
  - - Improve air quality 改善空氣質量
  - - Stormwater management 改善城市雨水管理
  - - Create natural habitat 建立自然棲息地
  - - Increase biodiversity 增加生物多樣性
  - - Insulate and absorb sound 隔音和吸音
  - - Possible urban farming 可作都市農業



# Urban heat island in Hong Kong 香港城市熱島



(Source: SCMP and Hong Kong Observatory)

# Rainstorm flooding problems in Hong Kong (2008)

## 在香港的暴雨水浸問題



# Potential benefits 潛在的好處



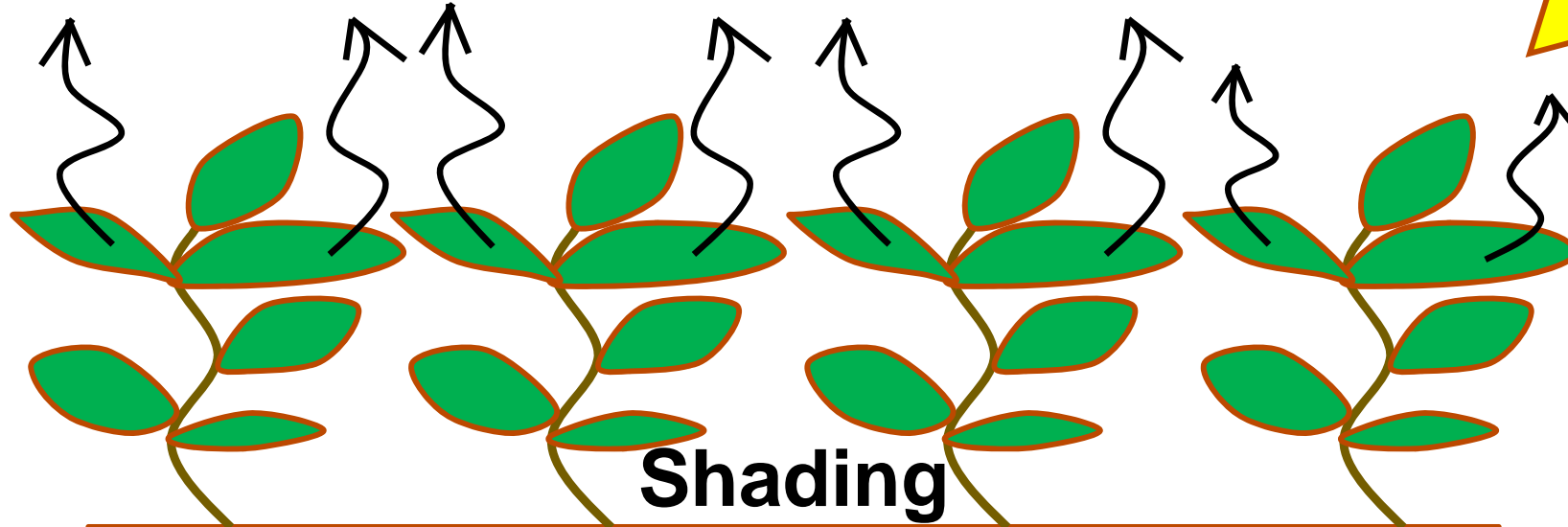
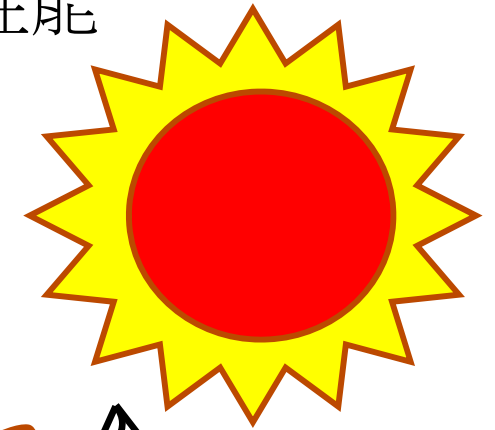
- 2. Economic benefits: 經濟的好處
  - - Improve roof durability 提高屋頂的耐久性
  - - Increase roof material lifetime 增加屋頂的壽命
  - - Reduce building cooling load and energy costs  
降低建築冷負荷和能源成本
  - - Provide open space & increase property value 提供開放空間，可增加物業價值
  - - Green building credit points & image  
綠色建築評估得分和形象



# Thermal properties of green roofs 綠化屋頂的熱學性能

Outdoor

Evapo-transpiration



Shading

Thermal mass

Insulating property

Roof slab

Indoor

# Potential benefits 潛在的好處



- 3. Social benefits: 社會的好處
  - - Aesthetic for city space 美化市容的空間
  - - Provide community green space & gardens for sports & leisure 提供社區綠地和花園，可作運動和休閒
  - - Community participation 提供社區的積極參與
  - - Provide education opportunities 提供教育機會
  - - Enhance local employment 加強地方就業





# School education green roof project 學校教育屋頂綠化工程

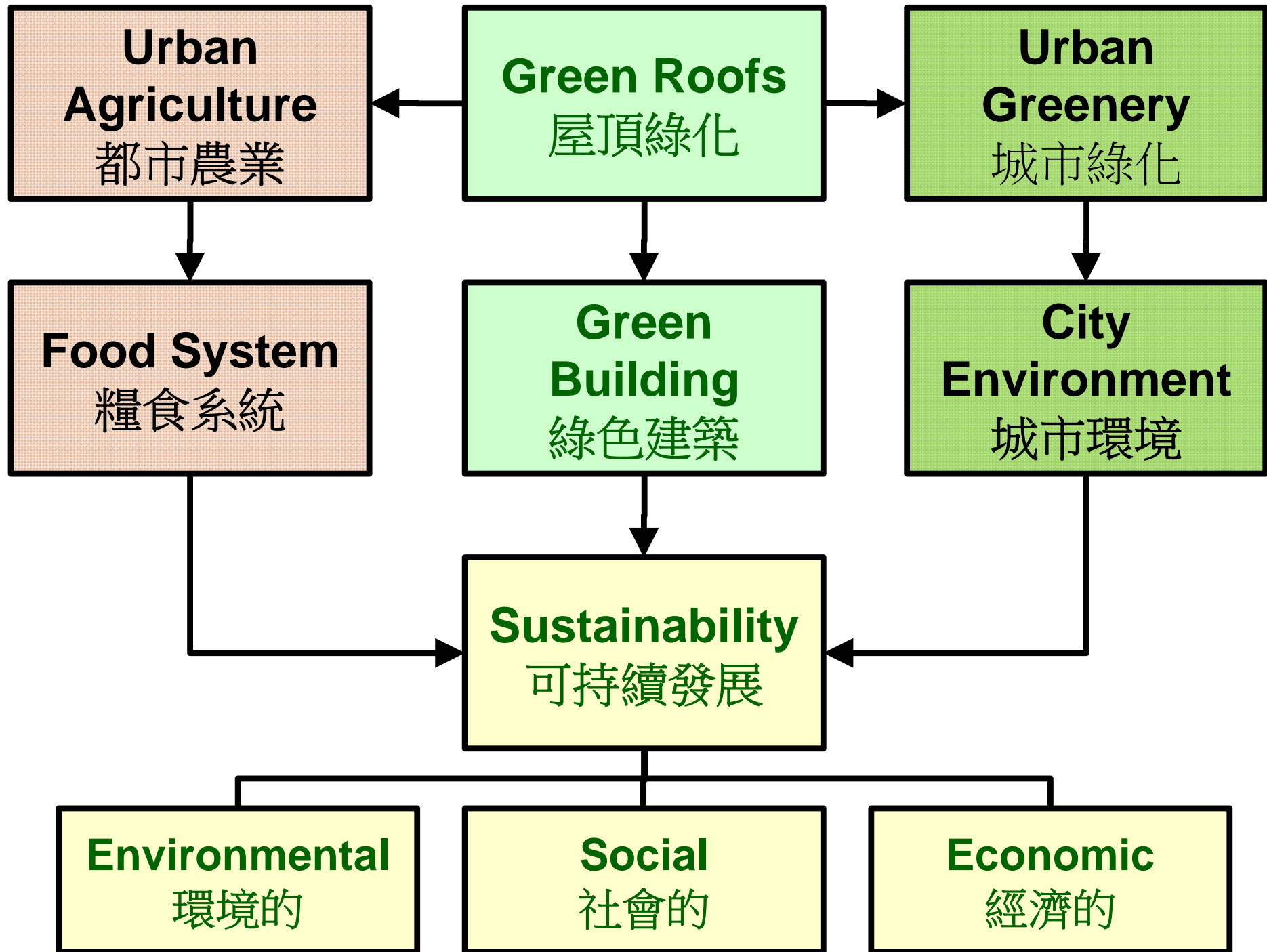


(Source: Ng Yuk Secondary School)

# School education green roof project 學校教育屋頂綠化工程



(Source: Environment and Conservation Fund)



# Green roof examples

## 屋頂綠化的例子



- Green roof application is growing fast in Hong Kong in recent years 屋頂綠化的應用，近年來在香港正在快速增長
  - 1. Government projects (as demonstration)  
政府項目 (如示範) (> 250 nos.)
  - 2. School projects (with incentives/subsidies)  
學校項目 (獎勵/補貼)
  - 3. Private projects (for “green” image)  
私人項目 (為“綠色”的形象)

# Examples of green roofs in Hong Kong 香港屋頂綠化的例子



Ocean Park 海洋公園



EMSD Headquarters 機電署總部



Parklane, TST 尖沙咀柏麗大道



HK Wetland Park 濕地公園

# Hong Kong Wetland Park Phases II 香港濕地公園第二期



(Source: Architectural Services Department)

# Greening at Tamar project 添馬艦發展工程的綠化



(Photos taken by Dr Sam C M Hui)

# New prison: green roof 新監獄的屋頂綠化



Lowu CSD

(Source: ArchSD)



# Government green roof projects 政府綠化屋頂項目



Sewage treatment plant 污水處理廠



Refuge room 垃圾房



Sewage pumping station  
污水泵站

(Source: Drainage Services Department and Housing Authority)

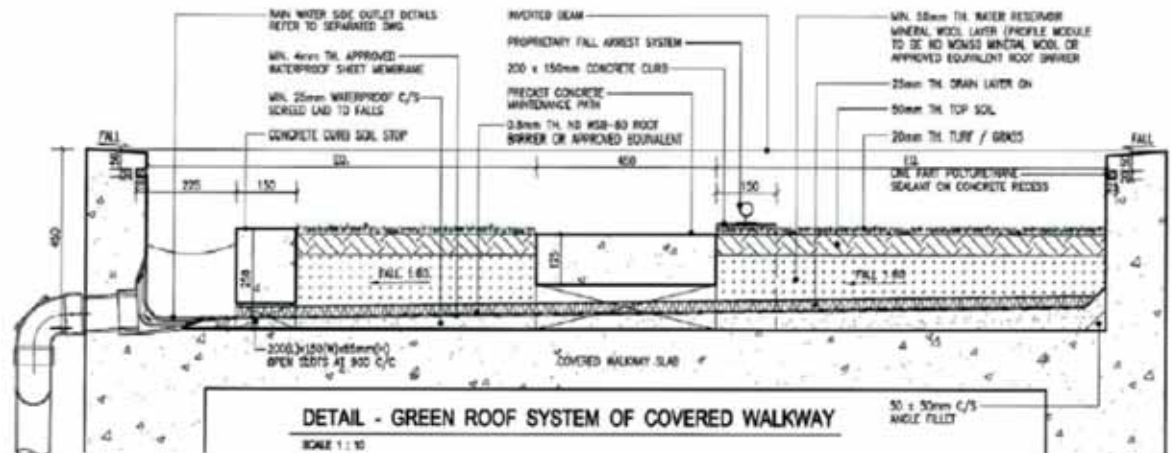
# Roof greening on covered walkway 有蓋行人道屋頂綠化



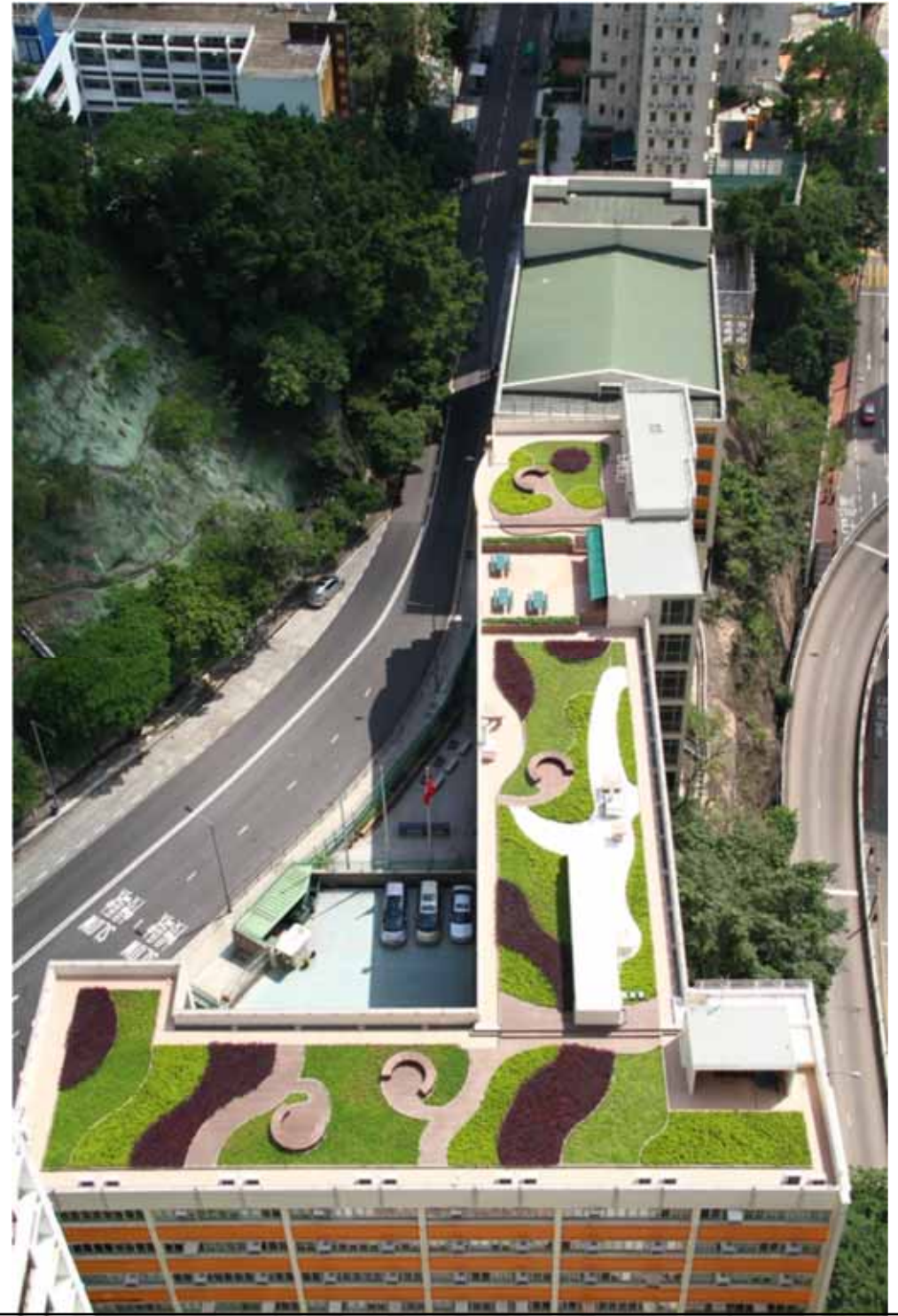
(Source: Housing Department, HK)



(Photo taken by Dr Sam C M Hui)

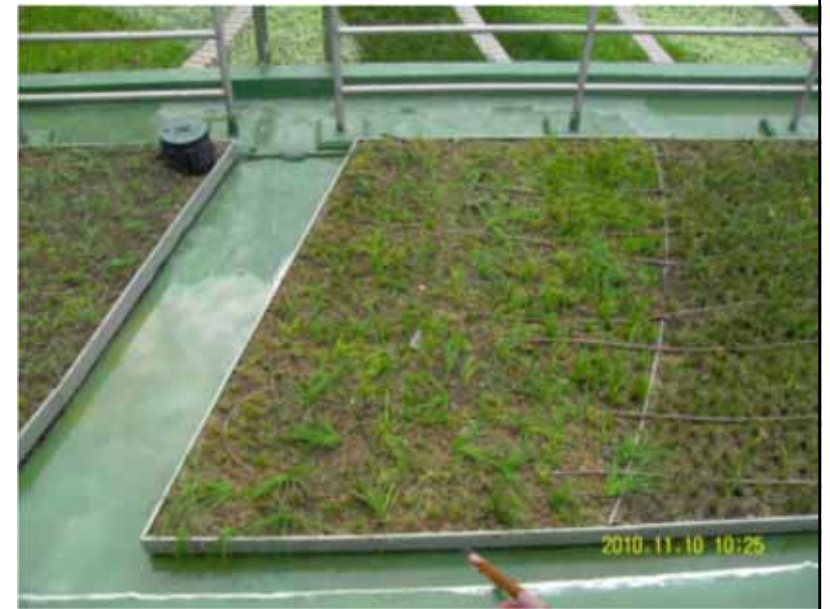


# School green roof project 學校屋頂綠化工程



(Source: Architectural Services Department)

# School green roof project 學校屋頂綠化工程



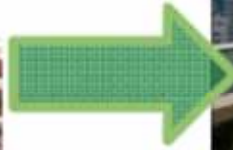
(Source: Architectural Services Department)

# HKU Centennial Campus 香港大學百週年校園

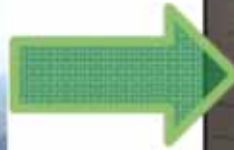


(Photos taken by Dr Sam C M Hui)

# Introduce greening on existing rooftops 現有的屋頂引入綠化



Wood deck was built as a path and resting area



Paving and vertical greening on roof garden

Source: The Hong Kong Jockey Club Headquarters

# Green roof farming (Hysan Place, Causeway Bay)

## 屋頂綠化農耕 (銅鑼灣希慎廣場)



(Photos taken by Dr Sam C M Hui)

# Vertical greening examples

## 垂直綠化的例子



- Common reasons for vertical greening 採用垂直綠化的常見原因：
  - Aesthetic (how it looks) 美學(它的外觀)
  - Cognitive (meaning) 認知(意義)
  - Experiential (use) 體驗(使用)
  - Planning and financial gains (\$) 規劃和財務收益
  - Pollution absorption (air) 吸收污染(空氣)
  - Ecology (habitats) 生態(棲息地)



# Vertical greening examples

## 垂直綠化的例子



- Application methods of vertical greening 垂直綠化的應用方法：
  - 1. Building façades or outdoor vertical surfaces 建築外牆或戶外垂直表面
  - 2. Interior walls or indoor vertical surfaces 室內牆壁或室內垂直表面
  - 3. Noise barriers (e.g. along the roads) 隔音屏障 (例如在道路兩旁)
  - 4. Slopes 斜坡

# An example of vertical greening 垂直綠化的一個例子



(Source: CityWalk, Tsuen Wan, 荃灣荃新天地, [www.citywalk.com.hk](http://www.citywalk.com.hk))

# A green wall in Central 中環的綠牆



## LUPA

The hollow trough, where the boys were laid, floated  
On the water, how great a fate the little ark carried!  
It drifted onwards towards a shadowy wood,  
And gradually settled where the depth lessened.  
There was a tree: traces remain, which is now called  
The Rumina fig, once Romulus' fig tree.  
A she-wolf, newly delivered, found the abandoned twins,  
Who would have thought the creature would not harm them!  
Far from harming them she helped them, and a wolf fed those  
Whom their kin would have allowed to perish.  
She stayed, cared for the tender infants with her tail,  
And licked their bodies with her tongue.  
You might know they were sons of Mars, without fear  
They [drank]... the milk not meant for them  
She gave her name to the place, and the place to the Lapert.

1817, 1818, 1819

# A green wall project in Kowloon Bay 在九龍灣一個綠化牆工程



Podium planters and vertical greenery

(18 Kowloon East)

# A green wall project in Wanchai 在灣仔一個綠化牆工程



(The Hennessy)



# Green wall for exhibition function 展覽活動的綠牆



# Government demonstration projects 政府示範項目



For a housing estate



For a school building



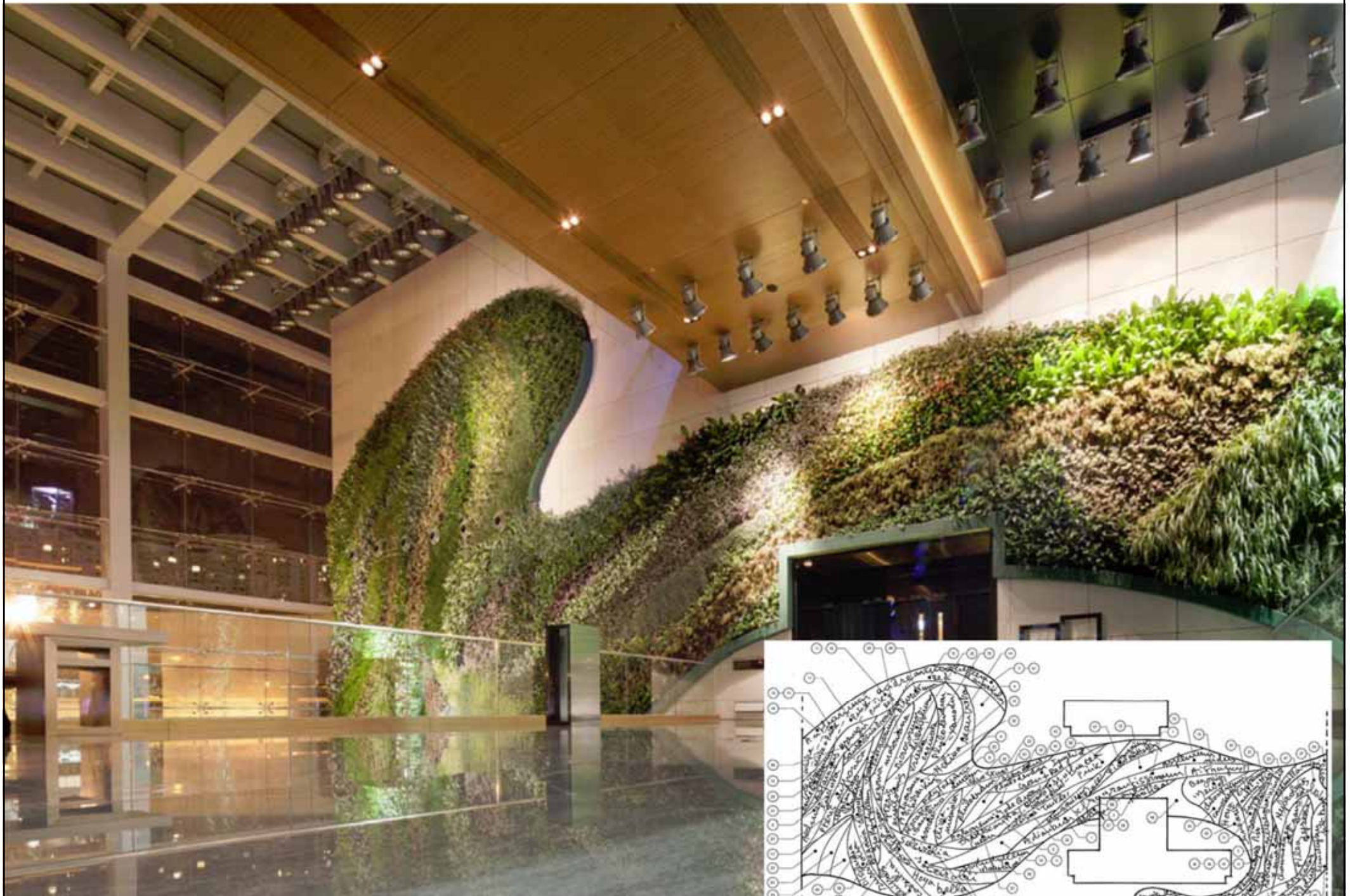
For a government building (EMSD Headquarters)

# A school green wall project 一所學校綠化牆項目





# An indoor green wall in a hotel 在酒店的一個室內綠化牆

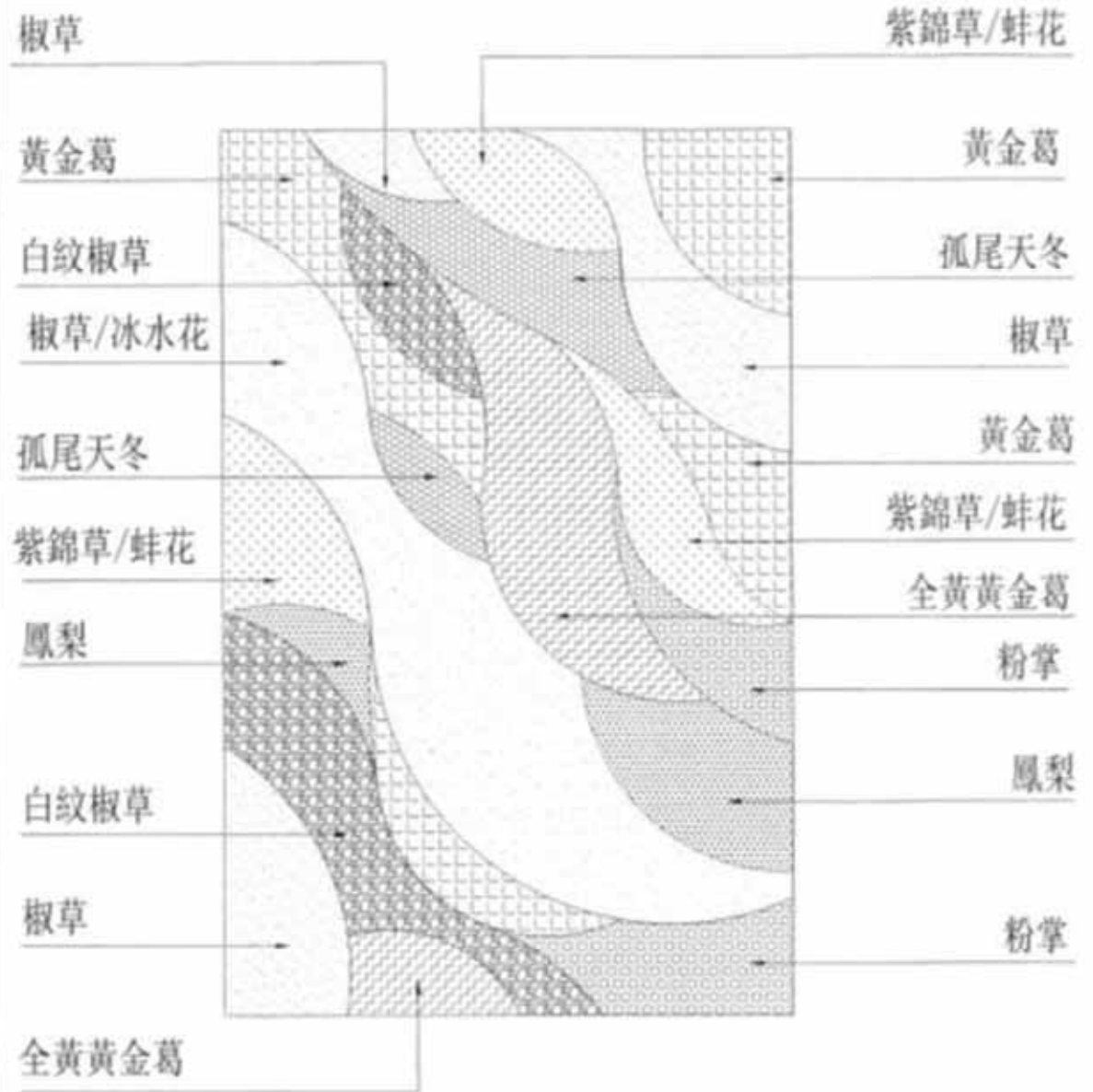


(Source: Hotel ICON)

# Indoor green wall 室內綠化牆



# Indoor green wall 室內綠化牆



(CityWalk 2, Tsuen Wan, 荃灣荃新天地2期)

1 ELEVATION  
Scale: 1:50

# Greening on highway structures 綠化公路結構



(Source: Highway Department, HK)

# Greening on slopes 斜坡上綠化



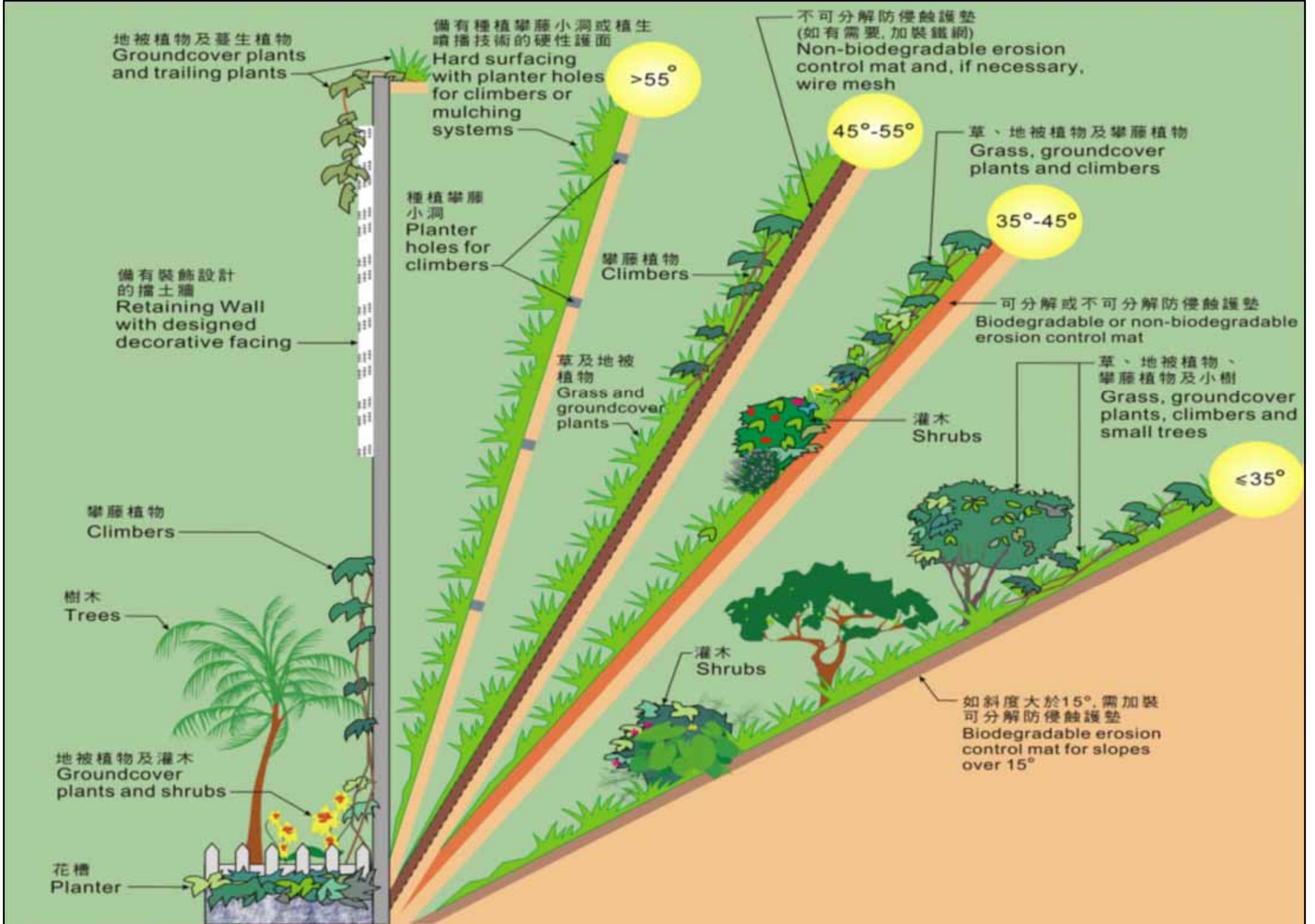
GEO Publication No. 1/2011

## Technical Guidelines on Landscape Treatment for Slopes



Geotechnical Engineering Office  
Civil Engineering and Development Department  
The Government of the Hong Kong  
Special Administrative Region

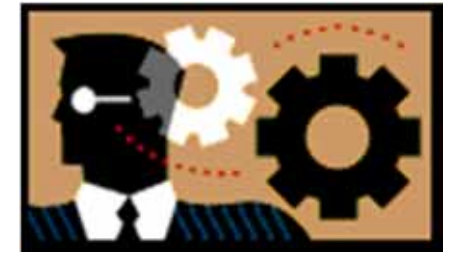
(Source: Civil Engineering and Development Department)



(Source: Civil Engineering and Development Department)

# Major considerations

## 主要考慮因素

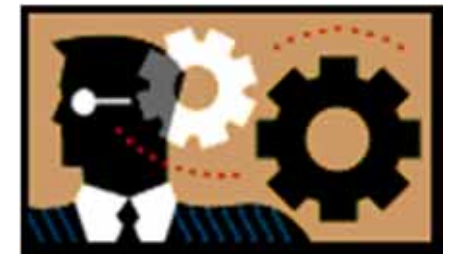


- Key factors for planning 主要規劃因素
  - Structural loading 結構負荷
  - Accessibility 能否容易到達
  - Waterproofing 屋面防漏水
  - Drainage 排水渠務
  - Maintenance 維護保養
- Other design considerations 其他設計考慮
  - Selection of plants (e.g. hardy plants) 選擇植物
  - Stakeholders' involvement & support 參與支持



# Major considerations

## 主要考慮因素



- Climatic factors 氣候因素
  - Typhoons: strong wind might blow away the vegetation and soil 颱風：強風會吹走植被土壤
  - Heavy rainfalls: hold and drain the rain water without creating pools of stagnant standing water 大雨：不積水池的雨水排水
  - High temperature: affect some plant species 高溫：某些植物物種的影響
  - Strong sunlight: solar and UV radiation 強烈的陽光：太陽能和紫外線輻射



# Major considerations

## 主要考慮因素

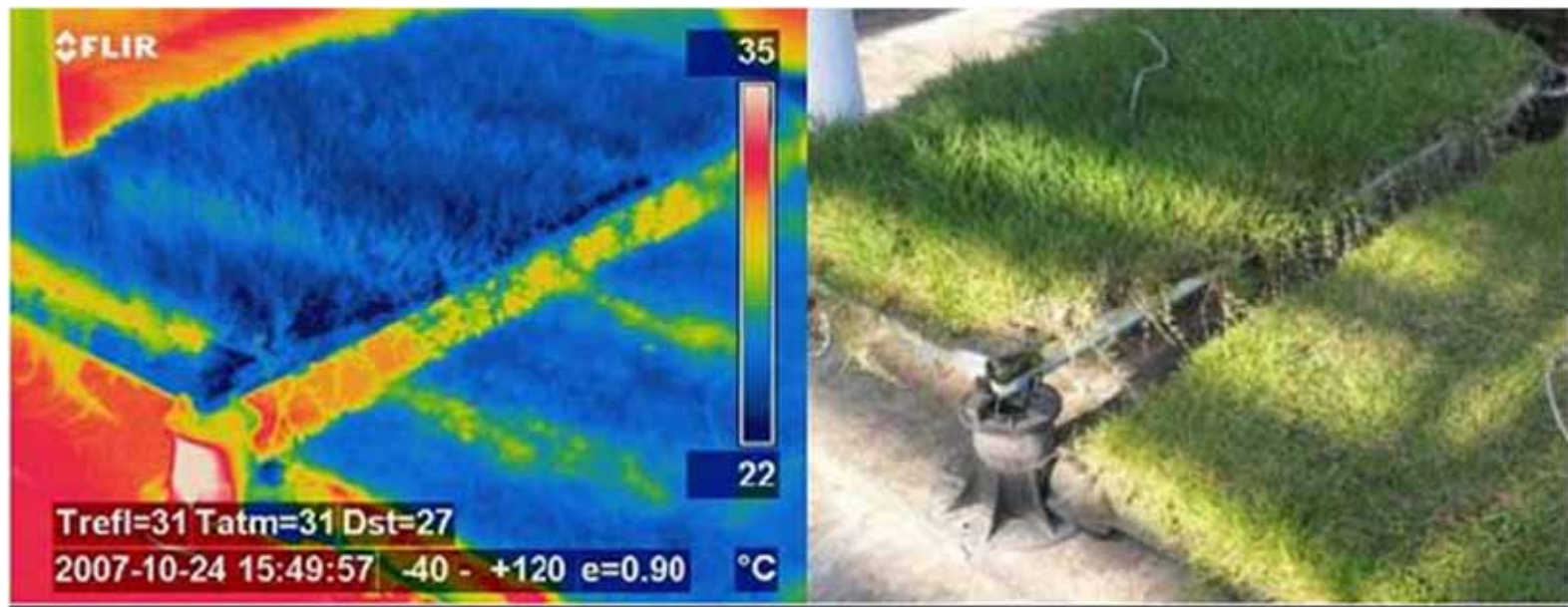


- High-rise buildings: very limited roof spaces  
高層建築：屋頂的空間非常有限
  - Better to apply green roofs to medium- or low-rise buildings/structures or podium roofs 更好地適用於中或低矮建築物/構築物或平台屋頂綠化
    - Podium/sky gardens 平台，空中花園
- Structural loading 結構荷載
  - Determine validity and cost 確定有效性和成本
  - For existing buildings 對於現有建築物
    - Light-weight greening systems 輕質綠化系統

# Green roof on a low-rise building 在低層建築的屋頂綠化



(Source: Hongkong Electric Co., Ltd.)



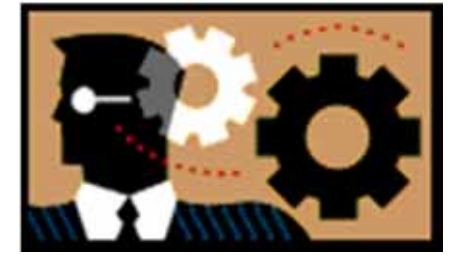
Infrared photo for assessing thermal effects  
評估熱效應的紅外照片



Typical hardy plants (sedums) used for green roofs  
用於綠化屋頂的典型頑強的景天植物

# Major considerations

## 主要考慮因素



- Costs and commitments 成本和承諾
  - Capital cost (direct & indirect costs) 資本成本(直接和間接成本)
  - Recurrent maintenance costs 經常維修保養費用
  - Life-cycle costs 生命週期成本
  - Risk of failure costs 失敗的風險成本
  - Maintenance commitments 維護承諾
  - Ownership 擁有權



# Development trends

## 發展趨勢

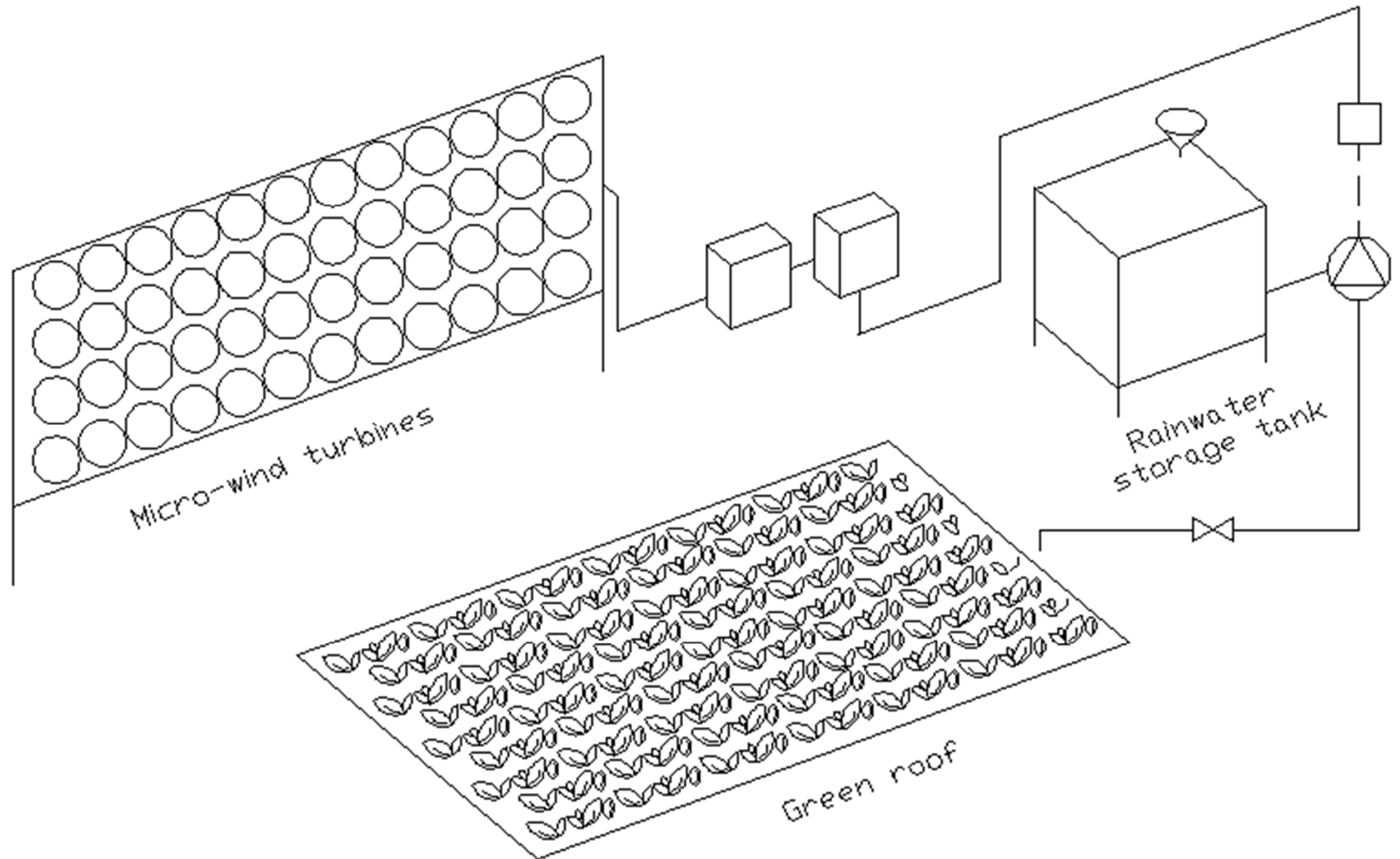


- Sustainable technologies 可持續發展技術
  - Rainwater harvesting 雨水收集
  - Renewable energy (e.g. solar photovoltaic & wind) 可再生能源(如太陽能光伏和風能)
  - Composting (for producing fertilizer) 堆肥(用於生產肥料)
- Farming & food production 農業和食品生產
  - Agricultural green roofs 農業屋頂綠化
  - Edible living walls 可食用的活生牆



# Integration of green roof, rainwater recycling and renewable energy

## 屋頂綠化，雨水回收利用和可再生能源的集成

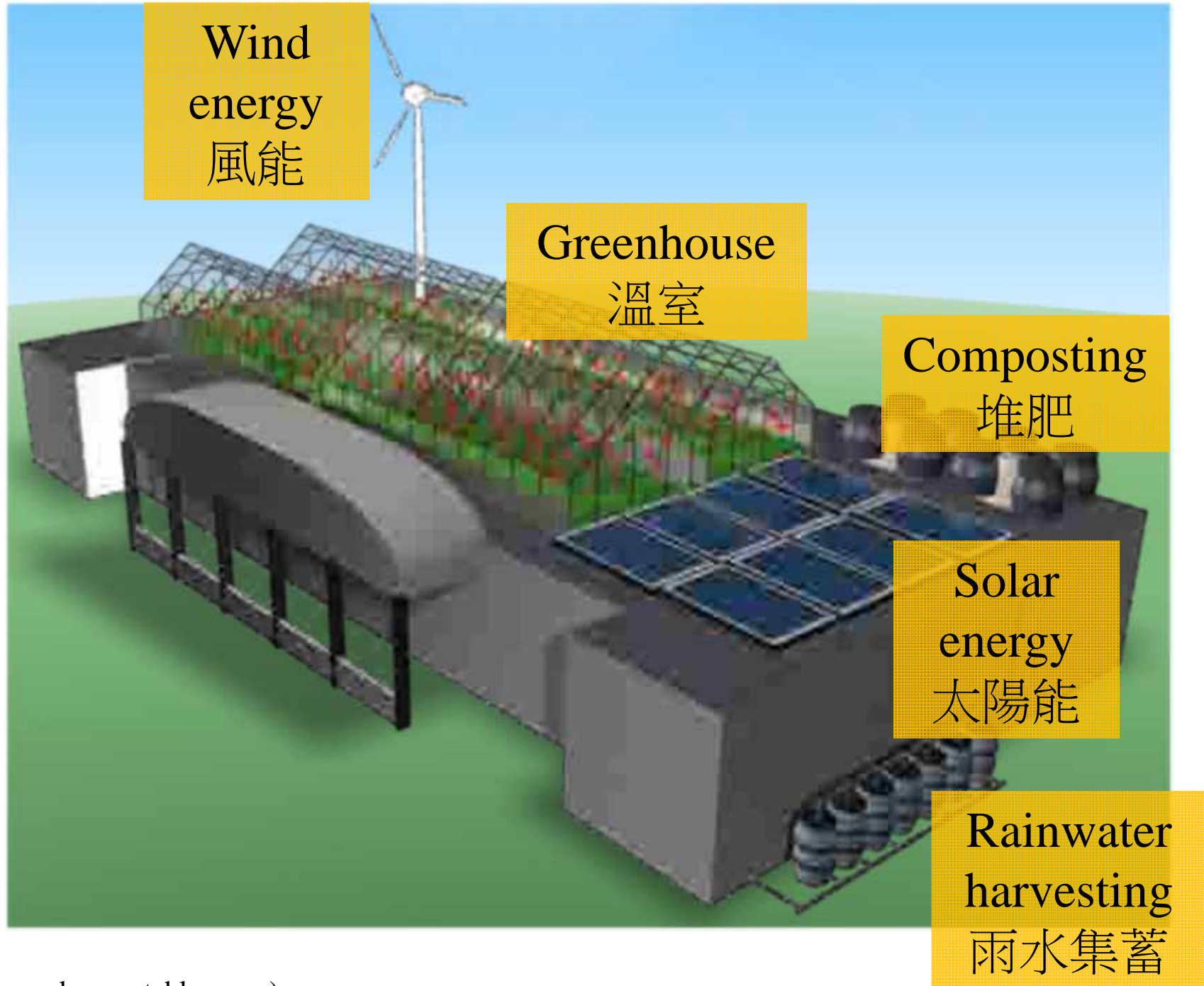


# Integration of green roof and solar energy systems

## 綠色屋頂和太陽能系統的整合

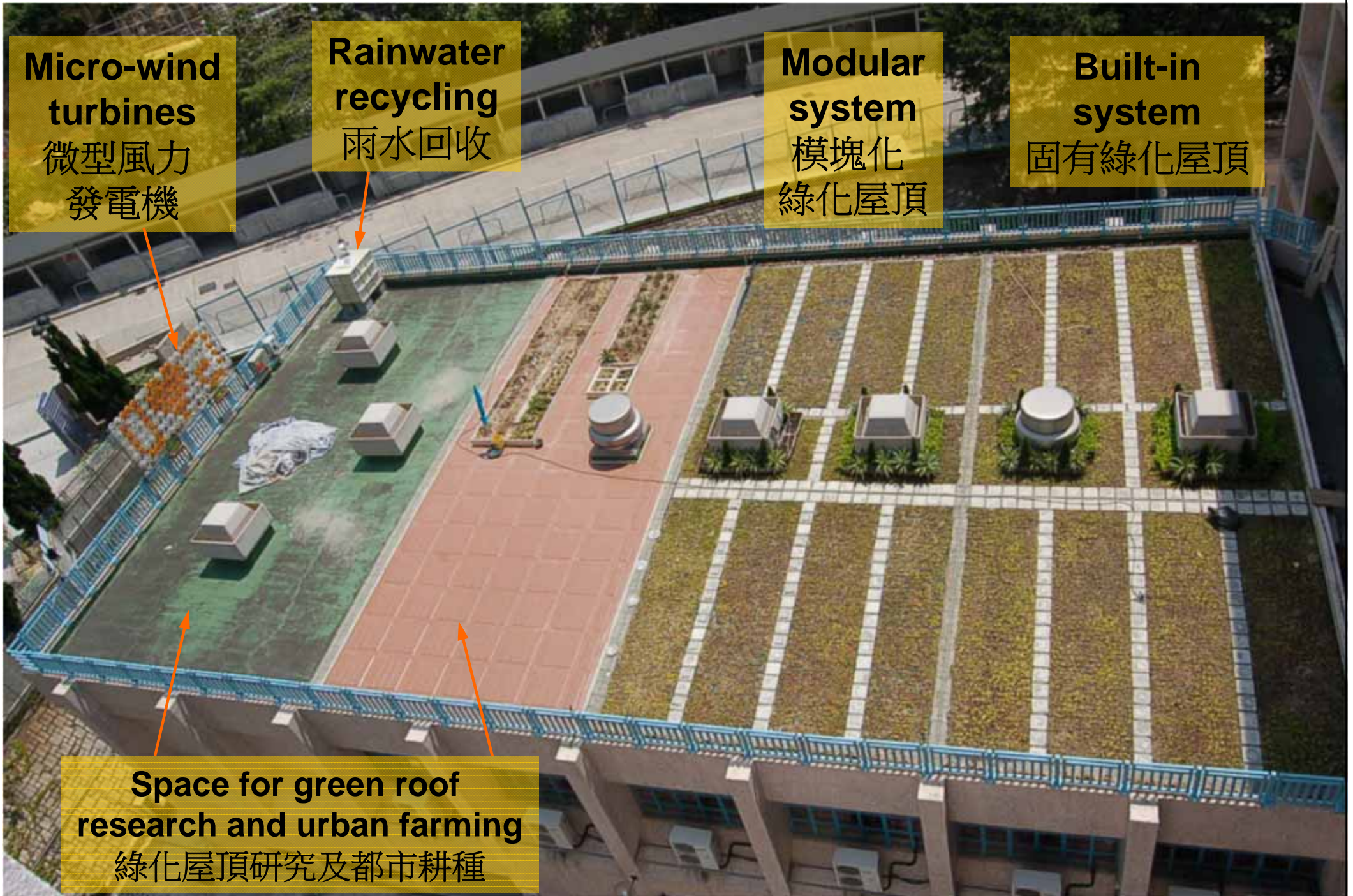


# Sustainable rooftop farming 可持續屋頂耕種





# Green roof research with integrated systems 綠色屋頂的綜合系統研究



# Urban farming on green roofs

# 綠化屋頂都市農耕



Farming on the roof  
農業上的屋頂



Vegetables and herbal plants  
蔬菜和草本植物



Water melon 西瓜



Green beans 青豆

(Photos taken by Dr Sam C M Hui; Acknowledgement: St. Bonaventure Catholic Primary School )

# Edible vertical garden 可食用垂直花園



# Soil-less green roof farming (purple potato) 無土屋頂綠化種植紫薯

[An elderly home in HK 香港的一間安老院]



(Photos taken by Dr Sam C M Hui)

# Conclusions 結論



- Green roofs and vertical greening are developing fast in Hong Kong 屋頂綠化和垂直綠化在香港正快速發展
- New techniques are applied to urban greening 新技術應用到城市綠化
- More research is needed to determine suitable technologies and policy for promoting them 需要更多的研究，以確定合適的技術和政策，以促進城市綠化

THANK YOU 謝謝 !!



(More information: <http://me.hku.hk/bse/greenroof/>)