IMechE YMS Technical Seminar on Green Roof Development in Hong Kong
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Green Roof Development in Hong Kong
香港綠化屋頂的發展

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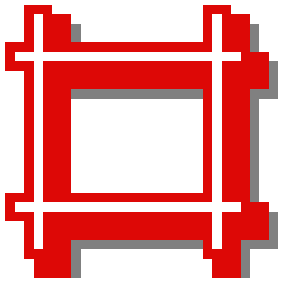
- Introduction 引言
- Potential benefits 潛在的好處
- Green roof examples 屋頂綠化的例子
- Vertical greening examples 垂直綠化的例子
- Major considerations 主要考慮因素
- Development trends 發展趨勢
- Conclusions 結論

Introduction 引言



- **Green Roofs**: roofs bearing vegetation –FLL*
  - "Living vegetation installed on the roofs"
  - "Vegetated roof" 植被屋頂
- **Green Roof System** – Definition 屋頂綠化系統
  - "A roof area of plantings/landscape installed above a waterproofed substrate at any building level that is separated from the ground beneath it by a man-made structure." – *NRCA Green Roof System Manual 2007*

生態屋頂，活生屋頂

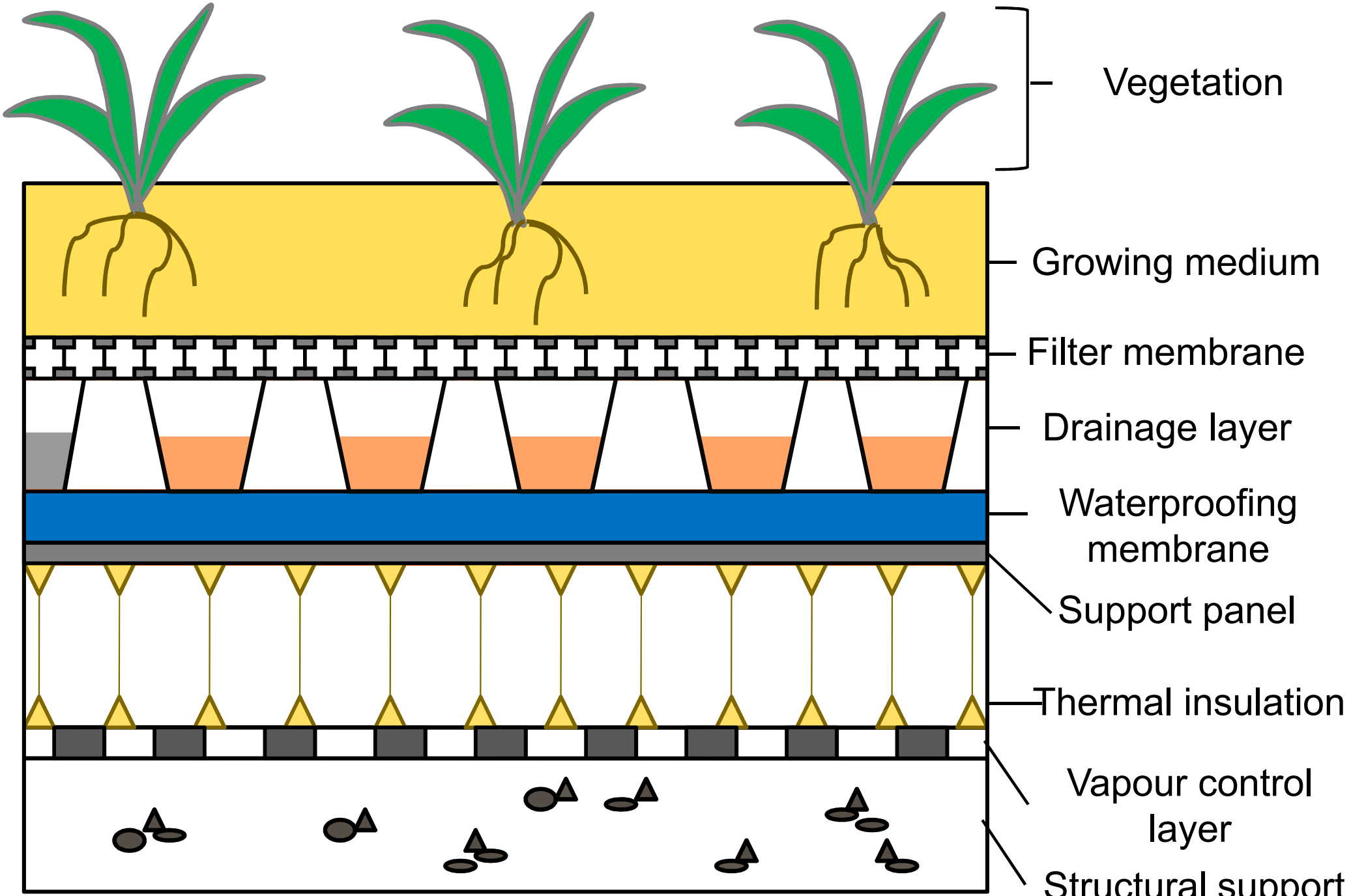
- Other green roof terms: Eco-roof, Living roof

* FLL = Research Society for Landscape Development and Landscape Design (Forschungsgesellschaft Landschaftsentwicklung Land-schaftsbau e.V.) (www.fll.de)

Table 1. Major types of green roofs and their characteristics

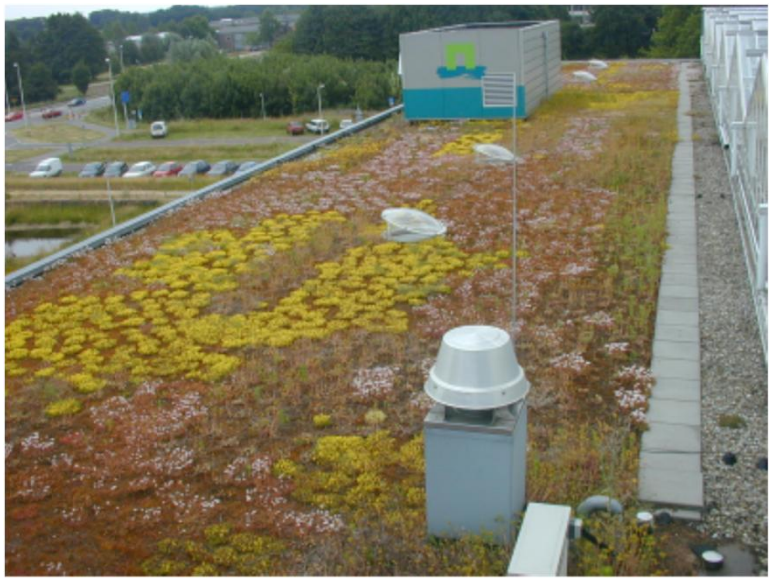
Characteristics	Extensive	Semi-intensive	Intensive
Depth of material	150 mm or less	Above and below 150 mm	More than 150 mm
Accessibility	Often inaccessible	May be partially accessible	Usually accessible
Fully saturated weight	Low (70-170 kg/m^2)	Varies (170-290 kg/m^2)	High (290-970 kg/m^2)
Plant diversity	Low	Greater	Greatest
Plant communities	Moss-sedum-herbs and grasses	Grass-herbs and shrubs	Lawn or perennials, shrubs and trees
Use	Ecological protection layer	Designed green roof	Park like garden
Cost	Low	Varies	Highest
Maintenance	Minimal	Varies	Highest

Typical structure of extensive green roof
粗放型屋頂綠化的典型結構



Examples of green roofs in the world 世界上綠化屋頂的例子

Solar Campus Jülich, Germany (11 Jul 2001)



IBN-DLO Wageningen, the Netherlands (2 Jul 2001)

Putrajava Int. Conven. Centre, Malaysia (30 Jun 2006)

Beitou Taipei Library, Taiwan (6 Aug 2007)

(Photos taken by Dr Sam C M Hui)

Introduction 引言

- Built-in green roofs 內置綠化屋頂
  - Installed in layers for the roof surface
  - More complex and permanent
  - Time needed for on-site installation & growing
  - Excess weight (180 to 450 kg/m^2)
  - Complexity of maintenance

- Modular green roofs 模塊化綠化屋頂
  - Prefabricated off-site, pre-grown, with modular design
  - Sub-divided into standard interchangeable parts

Modular green roofs
模塊化綠化屋頂

Vegetated mat system (www.elteasygreen.com)

Tray system (www.liveroof.com)

Sack system (www.greenpaks.com)

Construction process of modular green roofs
模塊化綠化屋頂的建設過程

Gウェイブ エコム 施工の流れ 作業工程

作業工程

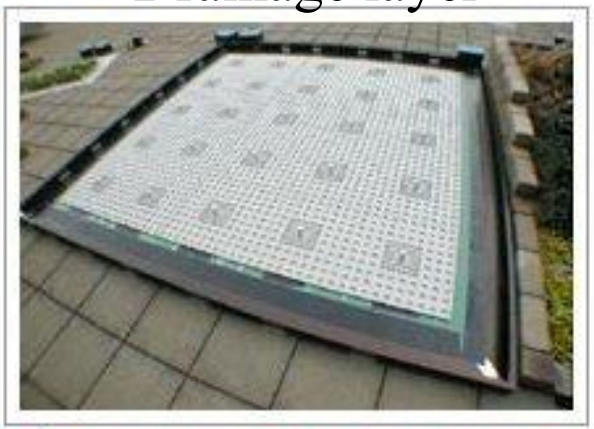
Waterproofing

1 防水層施工直後

Roof barrier layer

2 エコムテープ

Drainage layer

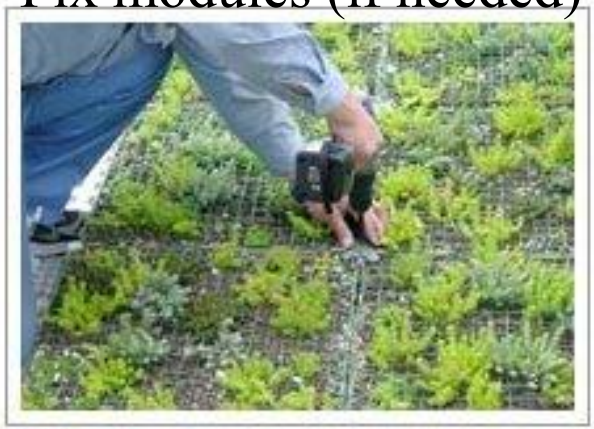


3 FDドレインEN FDウォール80E

Install modules

4 エコムユニット

Fix modules (if needed)



5 FDワッシャー

Completed

6 仕上がり

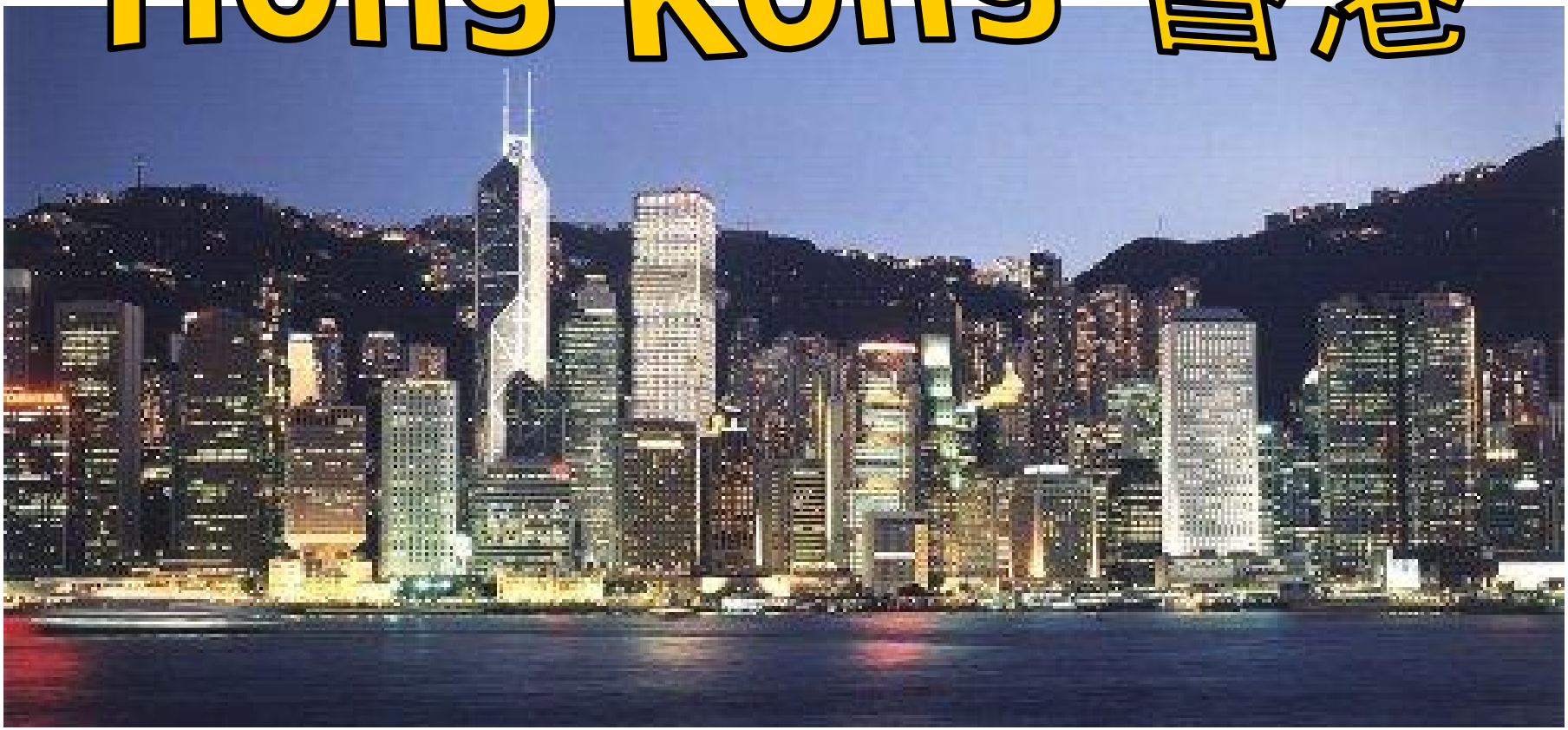
(Source: www.tajima-roof.jp)

Another type of “green roof” in Hong Kong?!

Building + **Green Roof**, but done in a wrong way.

(Image source: http://hk.apple.nextmedia.com/)

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^2
  - Population 人口: 7.18 millions
  - Population density 人口密度: 6,504 persons/ km^2

- 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

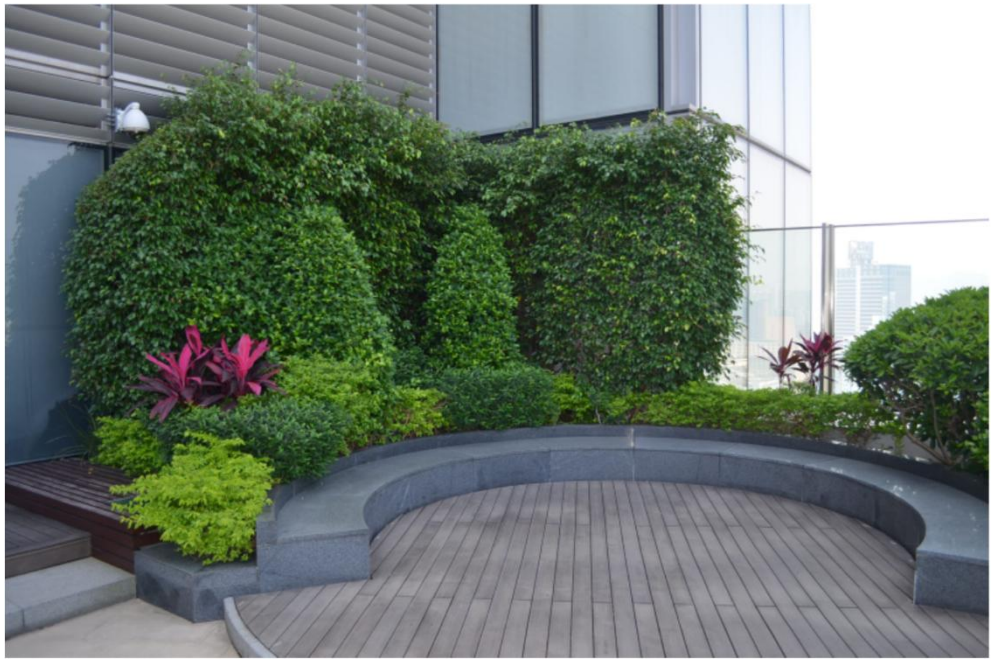
A residential podium garden 住宅平台花園

(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 green roof research 我們的屋頂綠化研究*
  - 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

(* See also http://ibse.hk/greenroof/)

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)

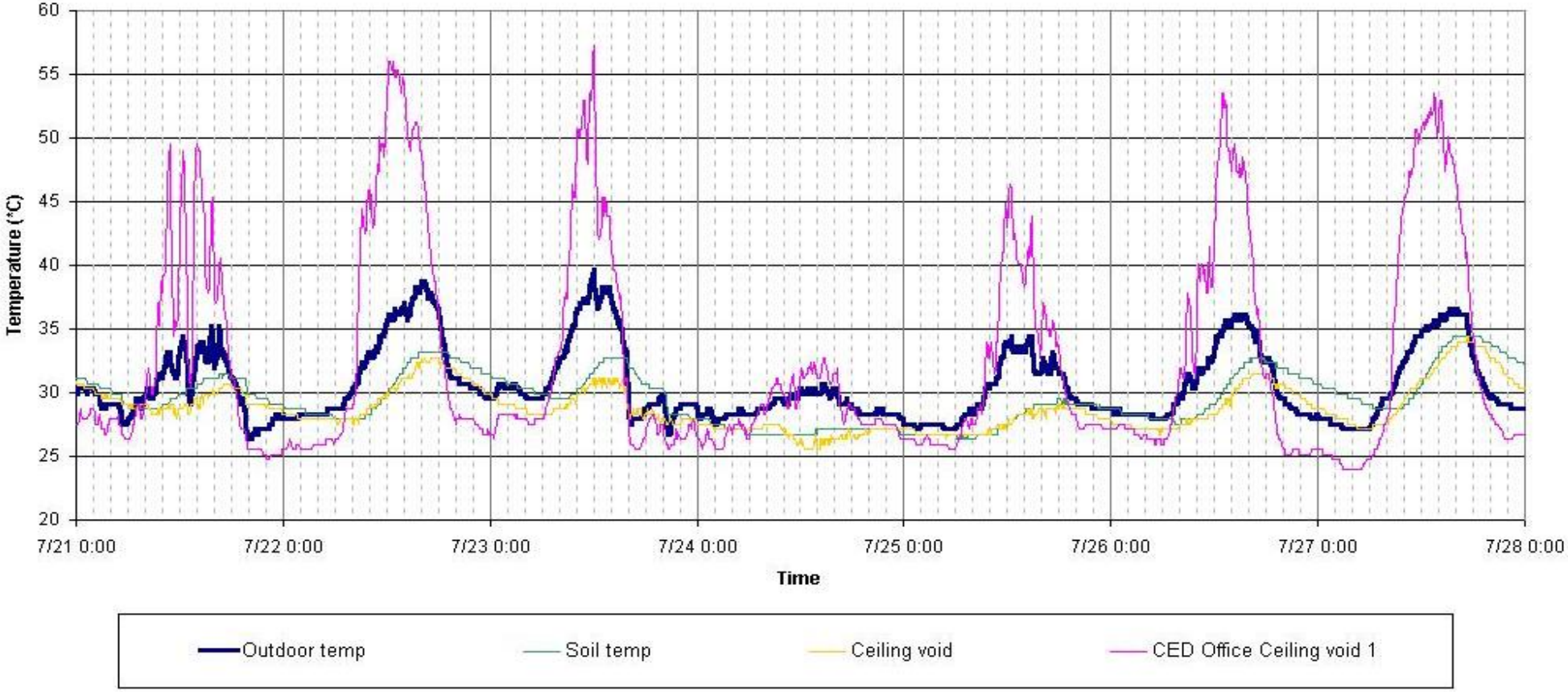
Green site office

Modular design

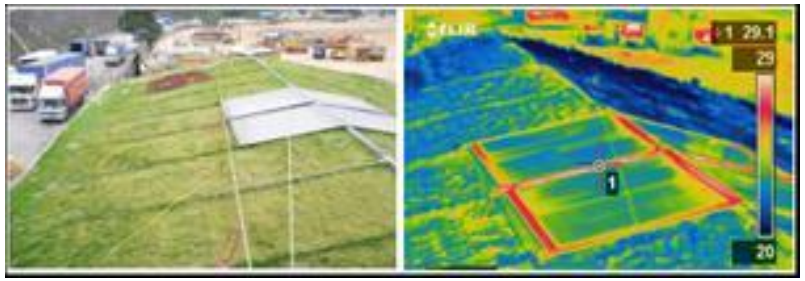
Green site office and typical site office

Water sprinkler

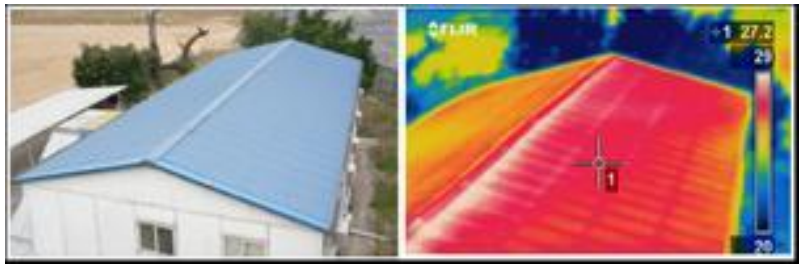
Green roof research at a construction site office in Hong Kong
在香港建築地盤辦事處的屋頂綠化研究



Infrared pictures:

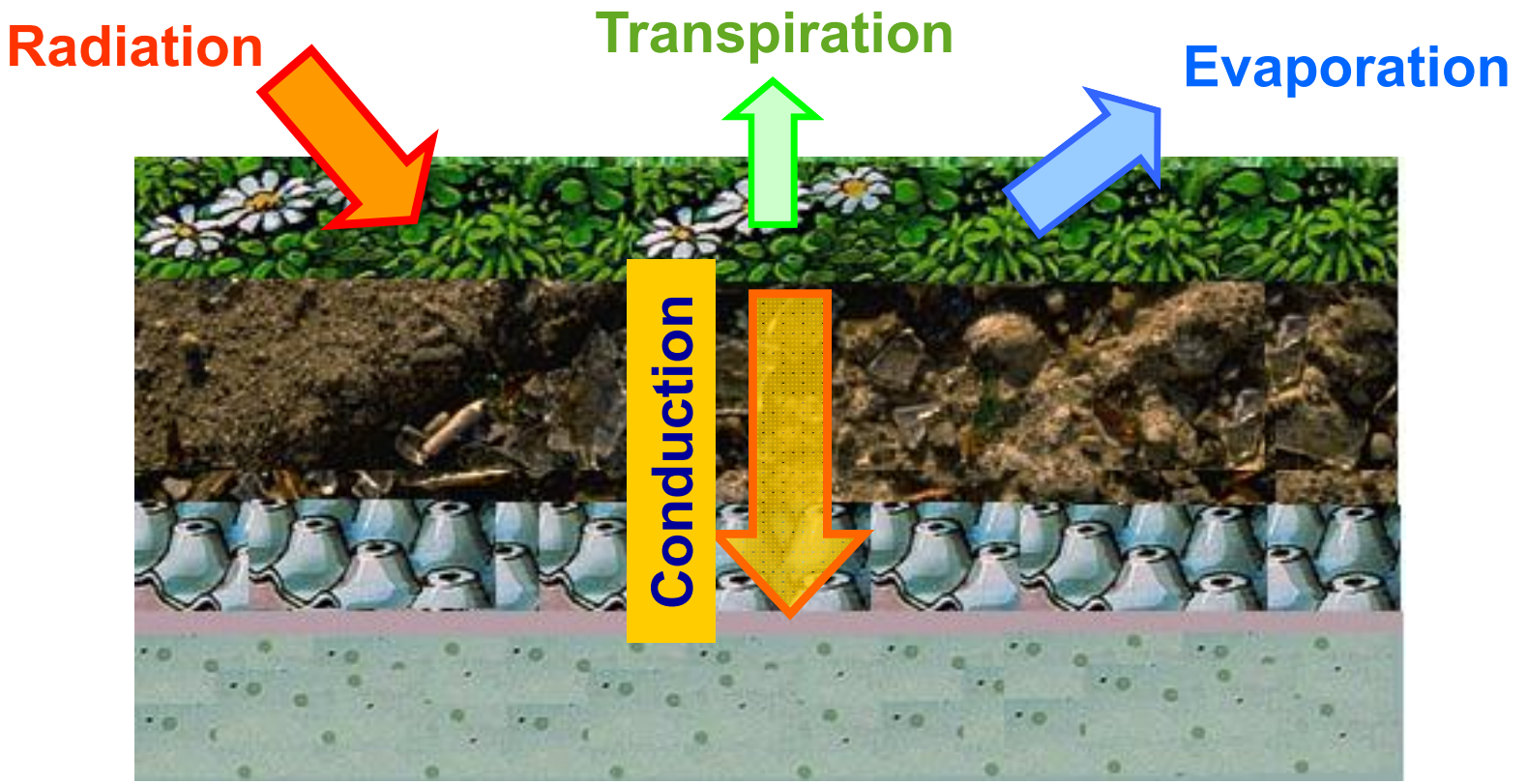


Green roof



Conventional roof

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



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

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

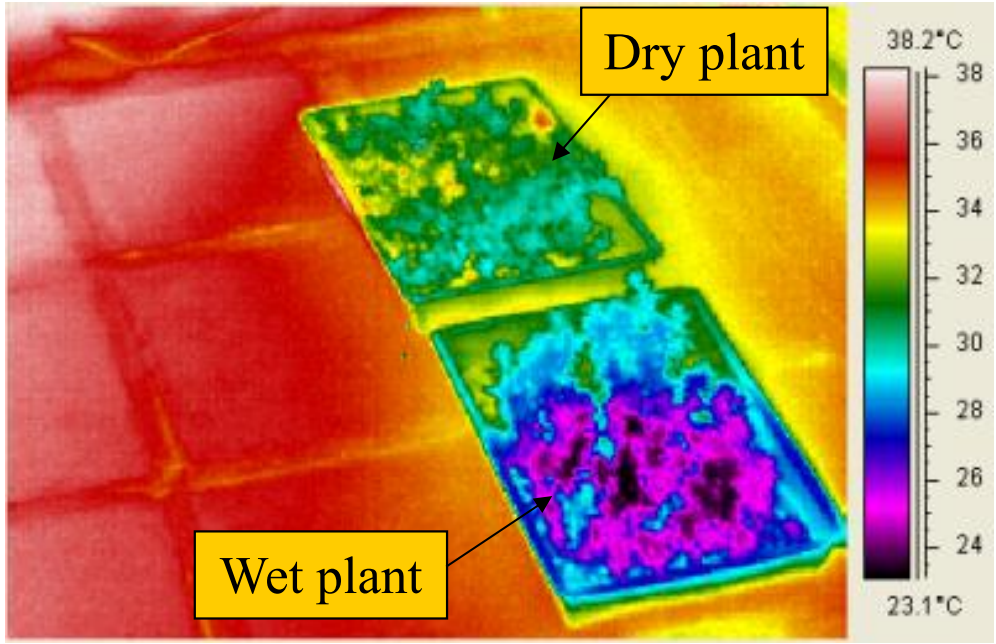
Conduction: $q'' = (T_{s1} - T_{s2}) / R_{total}$

Study of modular green roof systems (2007-2008)
模塊化屋頂綠化系統的研究

Aluminum trays

Wooden boxes

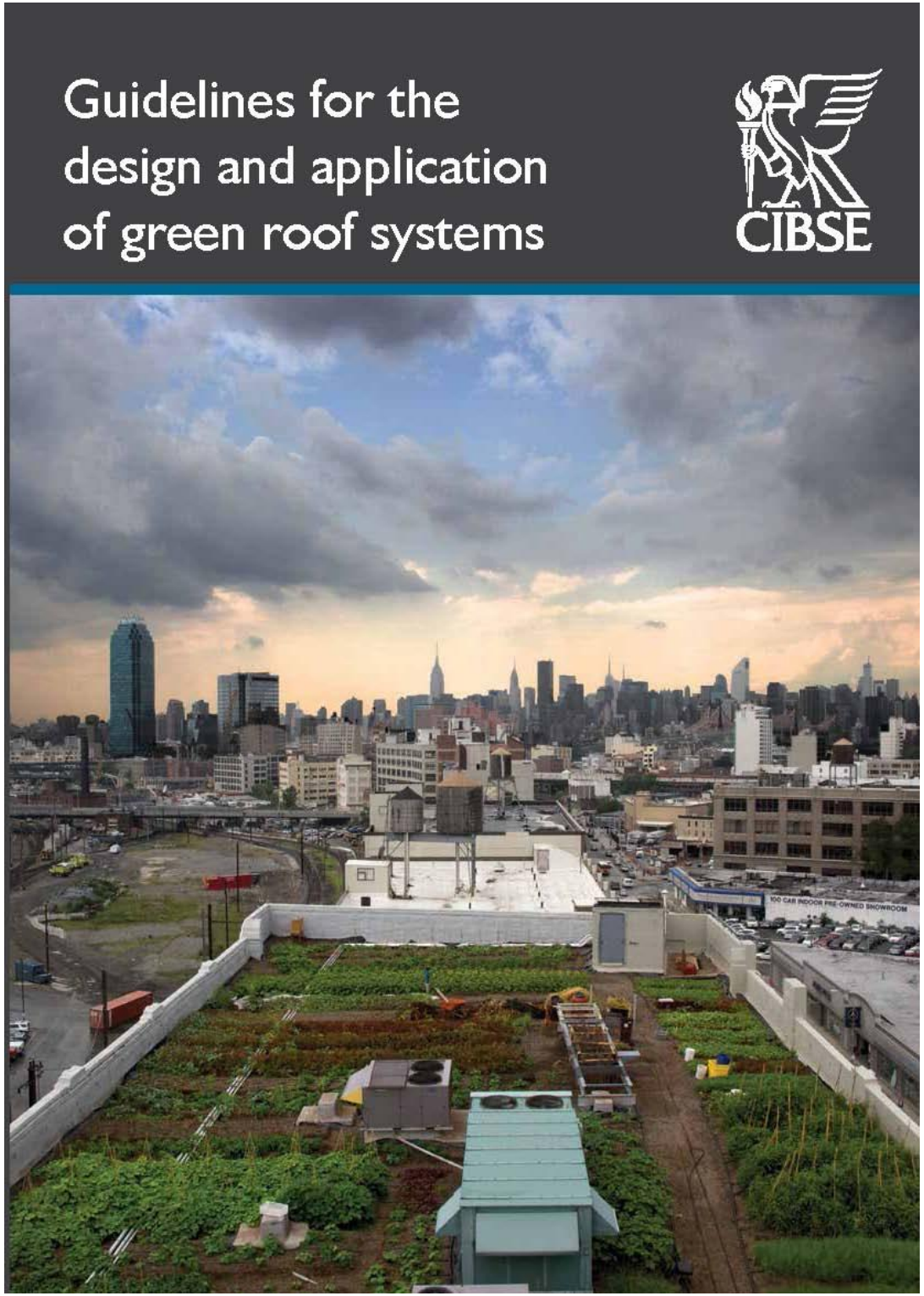
Plastic trays



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）



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

Green noise barrier 綠色隔音屏障

(Source: Highway Department, HK)

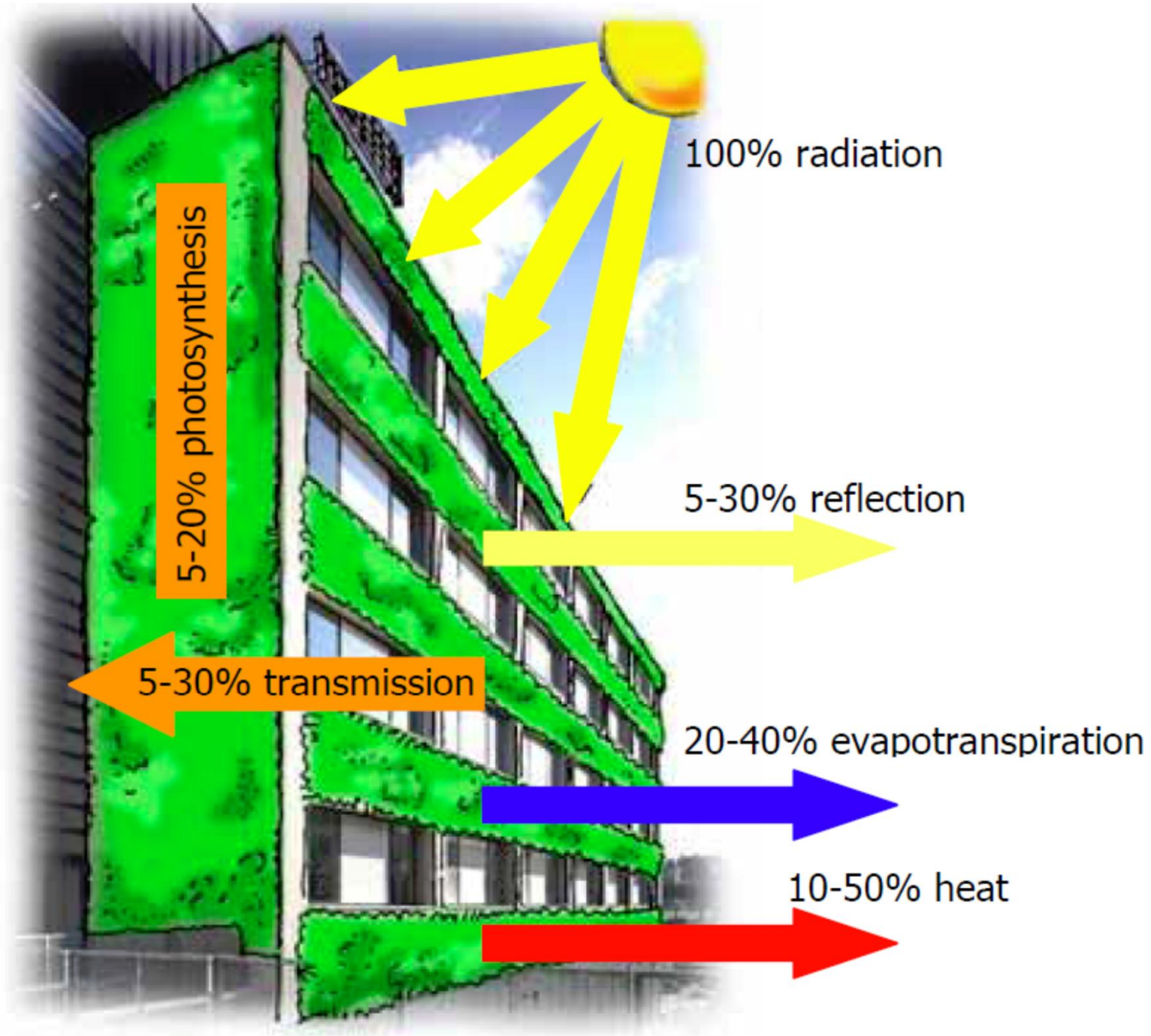
Indoor green wall 室內綠化牆

(International Commerce Centre 國際貿易中心)

(Photos taken by Dr Sam C M Hui)

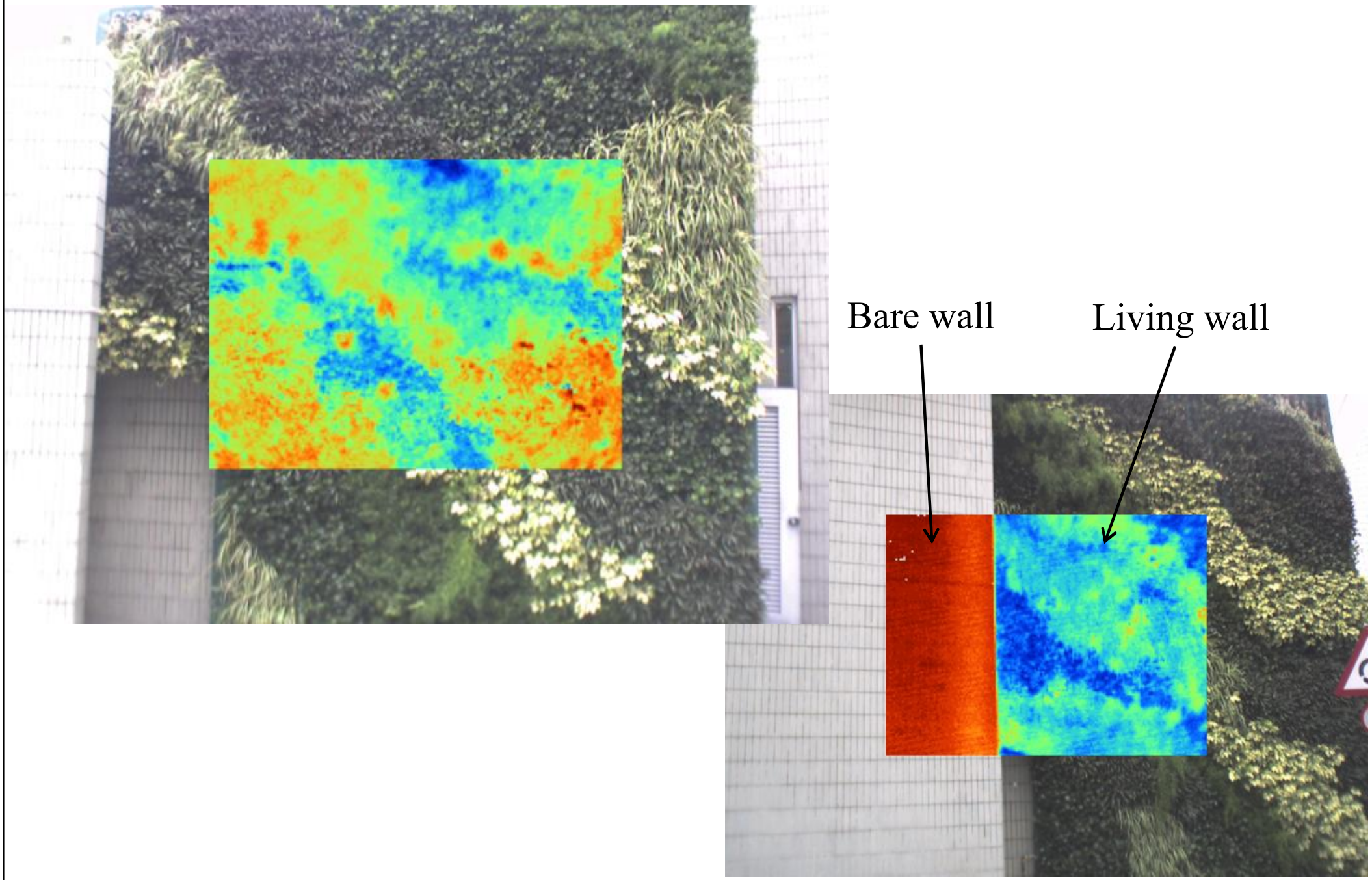
(International Finance Centre 國際金融中心)

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

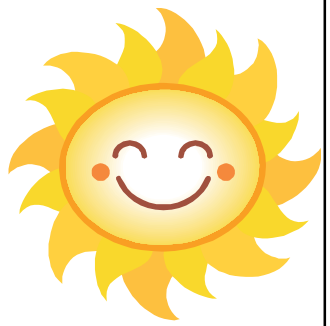


(Source: Ottelé, M., 2011. *The Green Building Envelope: Vertical Greening*, PhD Thesis, Technical University of Delft, The Netherlands.)

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

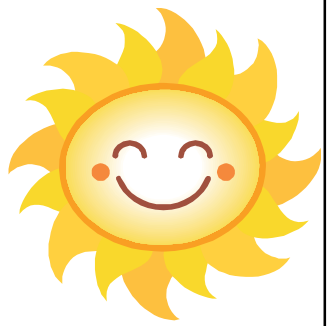


Potential benefits 潛在的好處



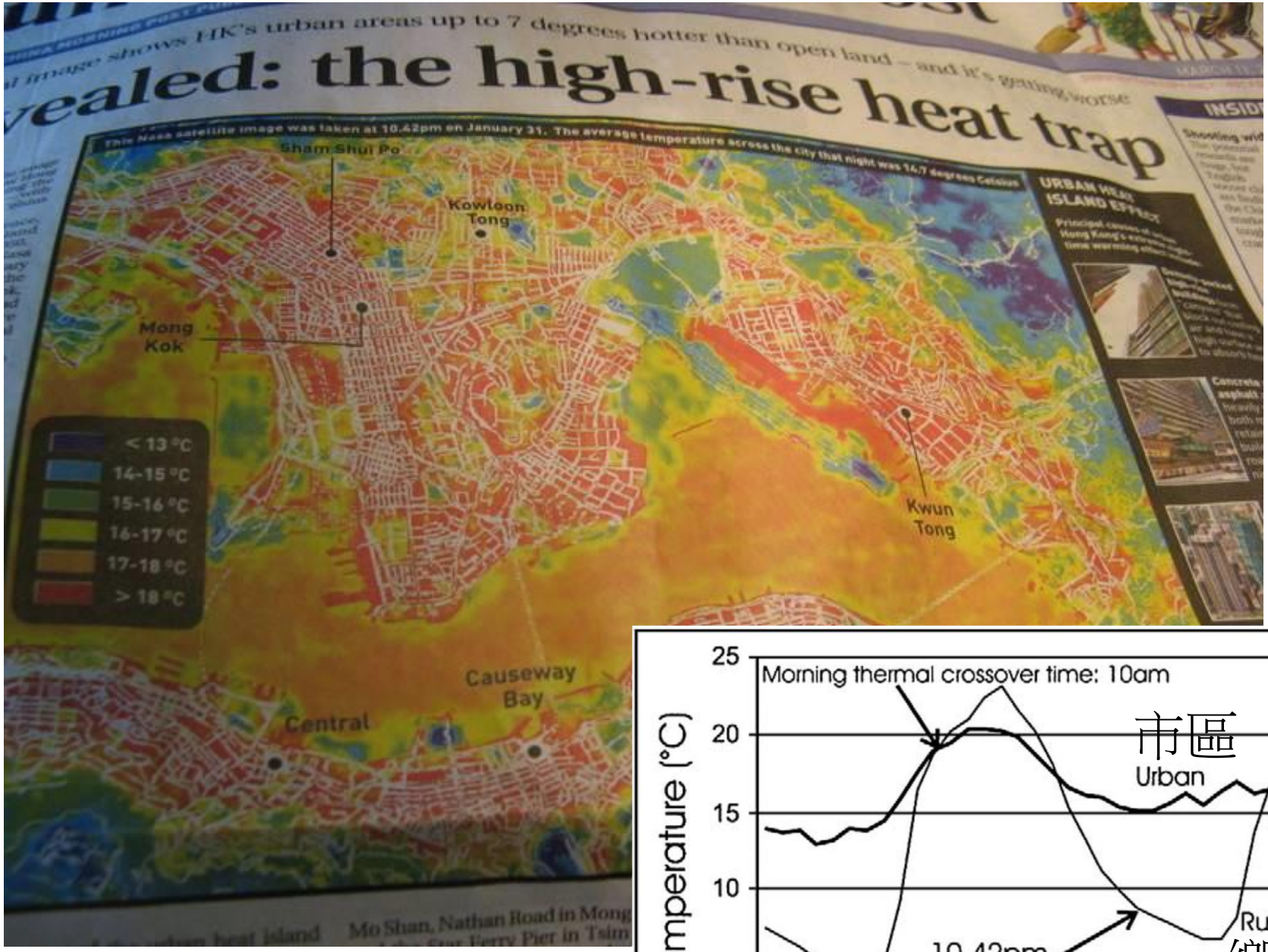
- Green roofs & vertical greening 綠化屋頂和垂直綠化
  - Building integrated vegetation 建築綜合性植被
  - Urban cityscape 城市景觀
  - Green infrastructure 綠色基礎建設
- Possible benefits: 可能的好處
  - 1. Environmental 環境的
  - 2. Economic 經濟的
  - 3. Social 社會的

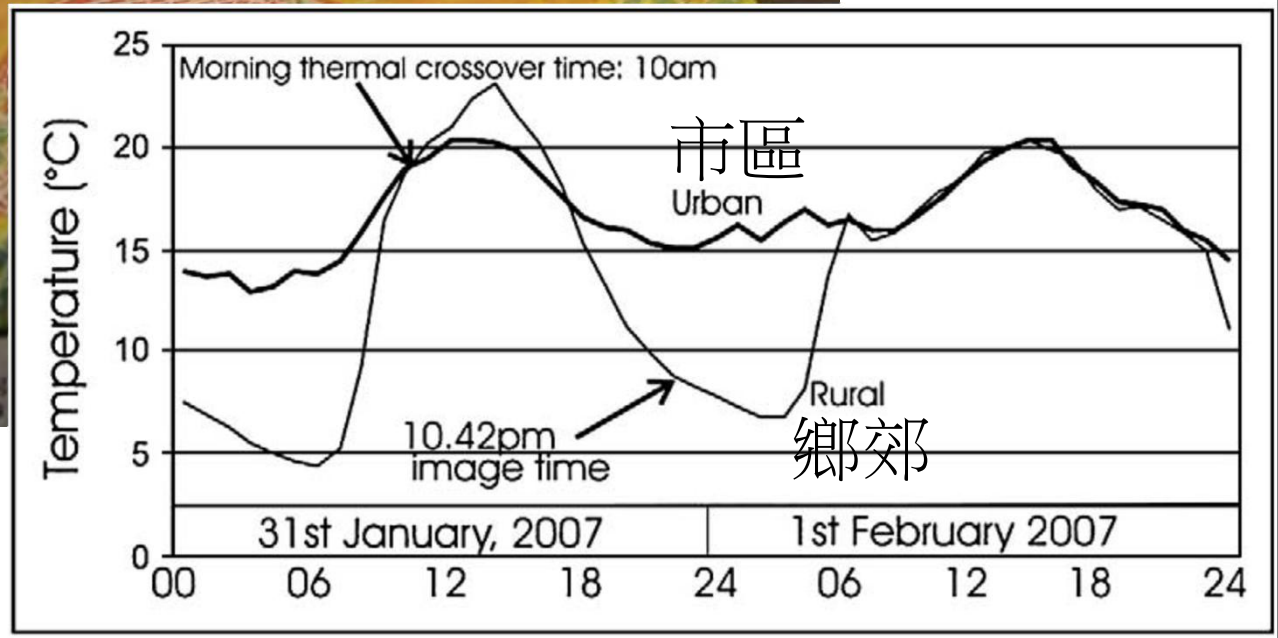
Potential benefits 潛在的好處



- 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)

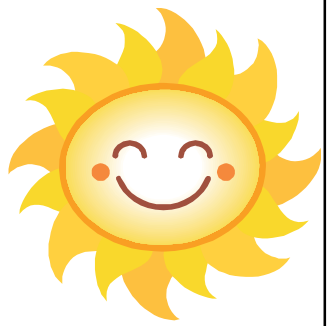
GREEN ROOF

TRADITIONAL ROOF

Rainstorm flooding problems in Hong Kong (2008)
在香港的暴雨水浸問題

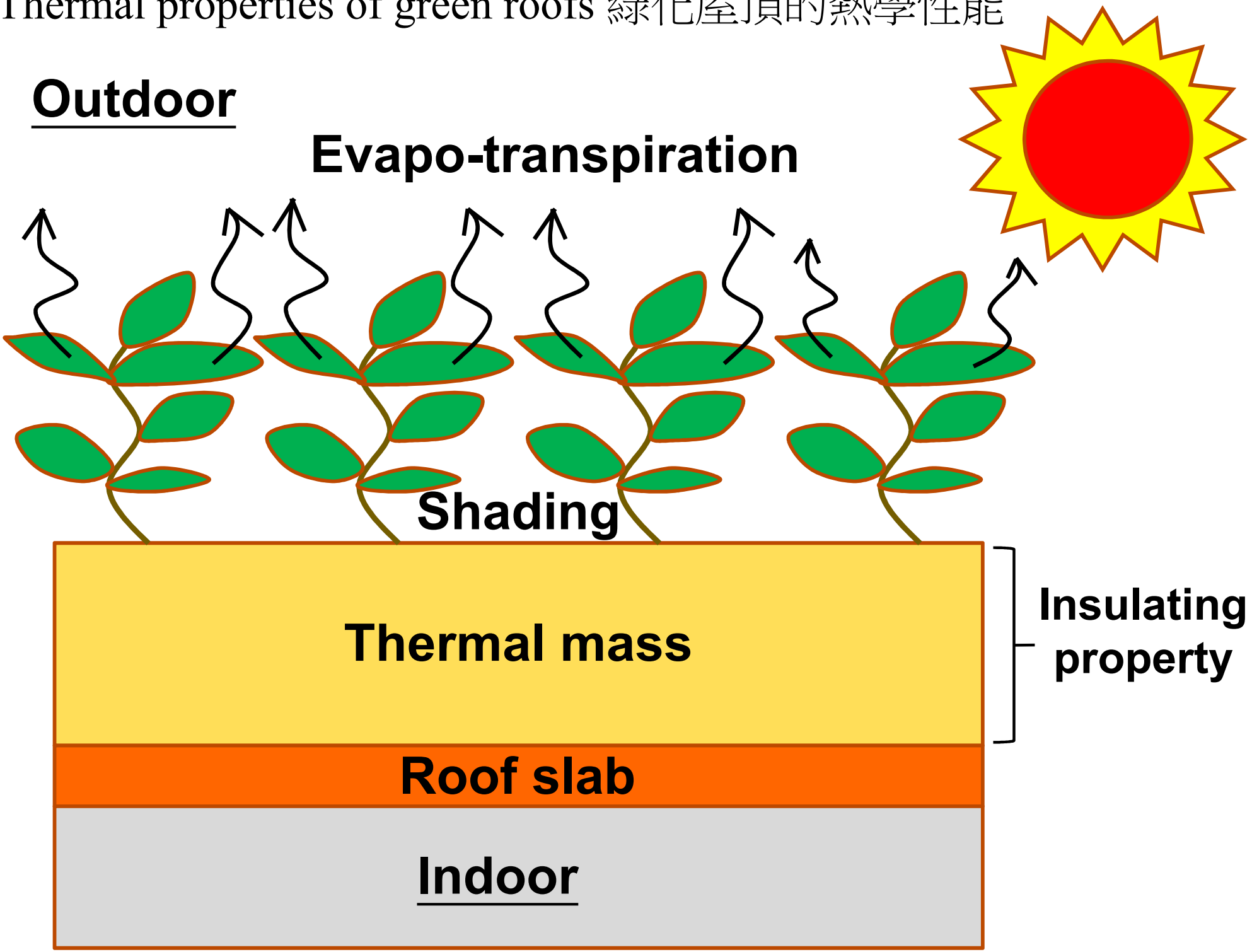
(Source: www.accuweather.com)

Potential benefits 潛在的好處

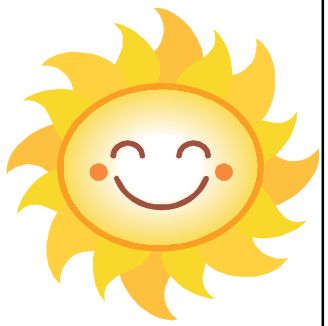


- 2. Economic benefits: 經濟的好處
  - - Improve roof durability 提高屋頂的耐久性
  - - Increase roof material lifetime 增加屋頂的壽命
  - - Reduce building cooling load and energy costs 降低建築冷負荷和能源成本
  - - Provide open space & increase property value 提供開放空間，可增加物業價值
  - - Green building credit points & image 綠色建築評估得分和形象

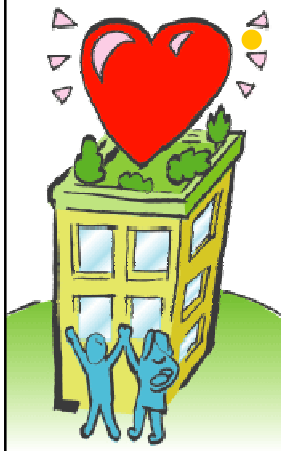
Thermal properties of green roofs 綠化屋頂的熱學性能



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

Urban farming & education

Horticultural therapy &
social functions

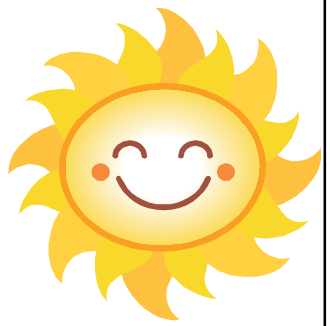
School education green roof project 學校教育屋頂綠化工程

(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)

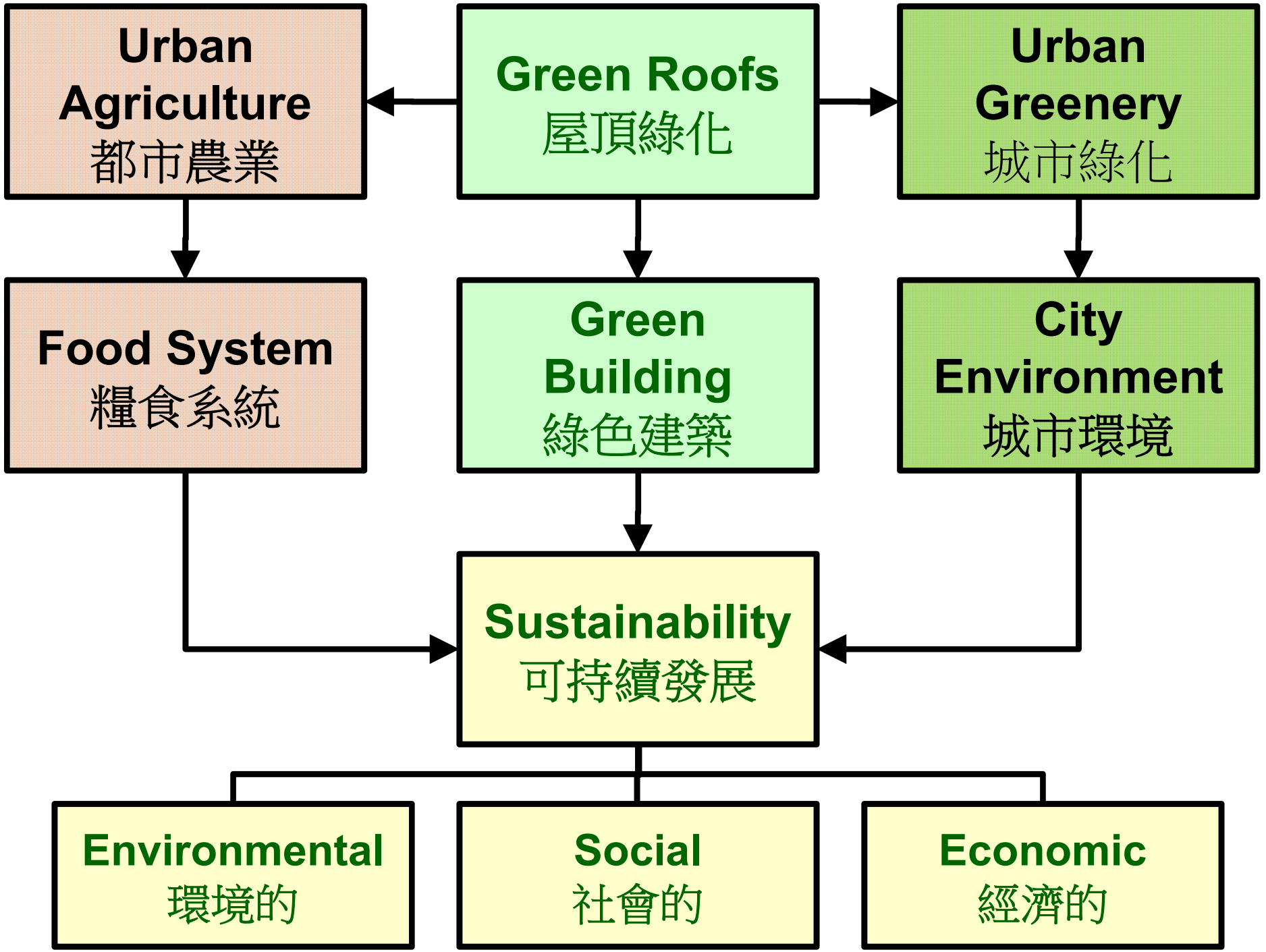
Potential benefits 潛在的好處



- Green Building Assessment 綠色建築評估
  - Such as BEAM Plus
  - They are becoming more and more popular and important
  - In fact, greening technology has significant implications to the assessment results
  - Green roofs can gain credit points in the green building assessment or rating schemes

BEAM Plus credit points of green roof systems

BEAM Plus criteria impacts:	Points
Sites Aspects (SA)	
Perequiste: Minimum landscape area	Required
SA 5: Ecological impact	1
SA 7: Landscaping and planters	1-3
SA 8: Microclimate around buildings (roof)	1
Materials Aspects (MA)	
MA 7: Recycled materials (roof components)	1
Credit 5: Local/Regional materials	1-2
Energy Use (EU)	
EU 1: Reduction of CO_2 emission	1-15
EU 2: Peak electricity demand reduction	1-3
Water Use (WU)	
WU 1: Water efficient irrigation	1
WU 6: Effluent discharge to foul sewers	1
Secondary credit impacts:	Points
Water Use (WU)	
WU 4: Water recycling (rainwater)	1-2
Innovations and Additions (IA)	
IA 1: Innovative techniques	1-5


Urban Agriculture
都市農業
Green Roofs
屋頂綠化
Urban Greenery
城市綠化
Food System
糧食系統
Green Building
綠色建築
City Environment
城市環境
Sustainability
可持續發展
Environmental
環境的
Social
社會的
Economic
經濟的

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

(Photos taken by Dr Sam C M Hui)

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

(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

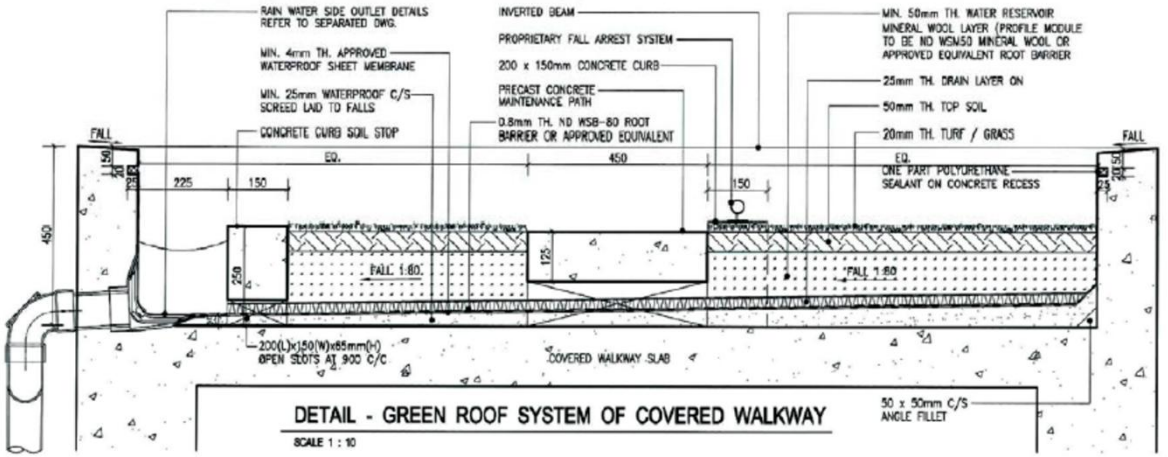
Sewage pumping station
污水泵站

(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)

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

(Source: Development Bureau, HK)

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)

A green wall in Central 中環的綠牆

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

(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

(Source: www.greening.gov.hk)

Government demonstration projects 政府示範項目

For a housing estate

For a school building

For a government building (EMSD Headquarters)

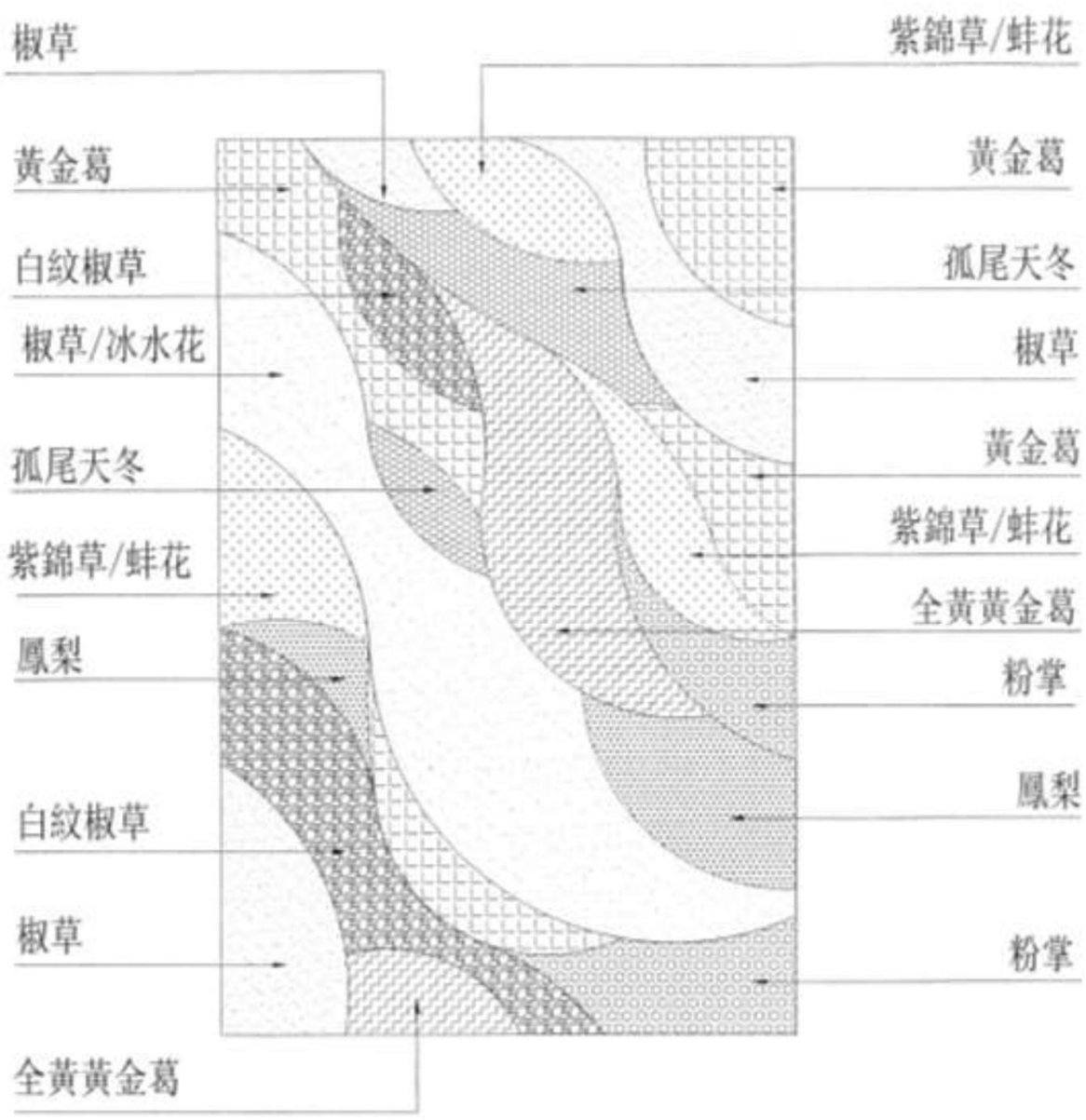
(Source: www.greening.gov.hk)

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



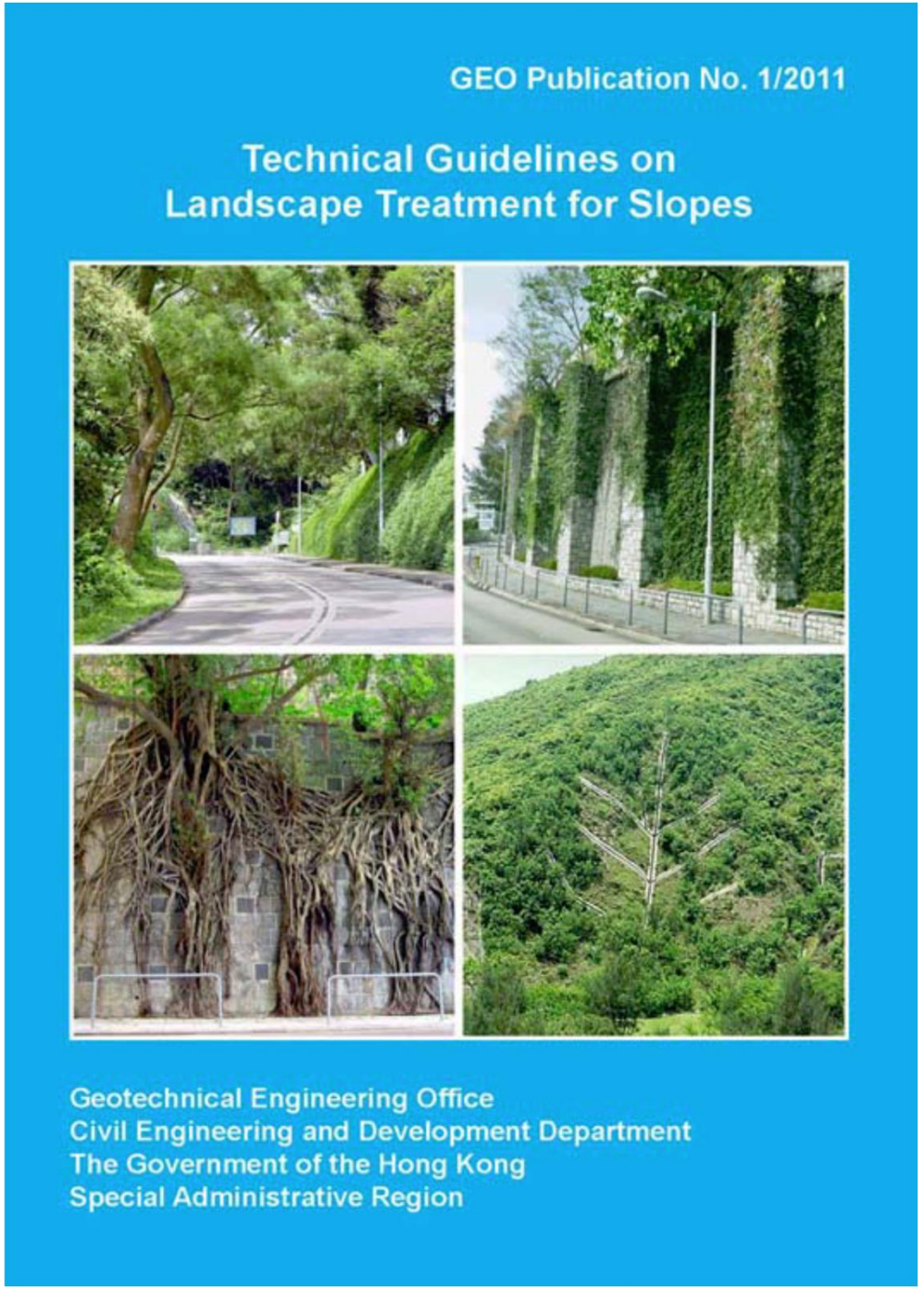
1 ELEVATION
Scale: 1:50

(CityWalk 2, Tsuen Wan, 荃灣荃新天地2期)

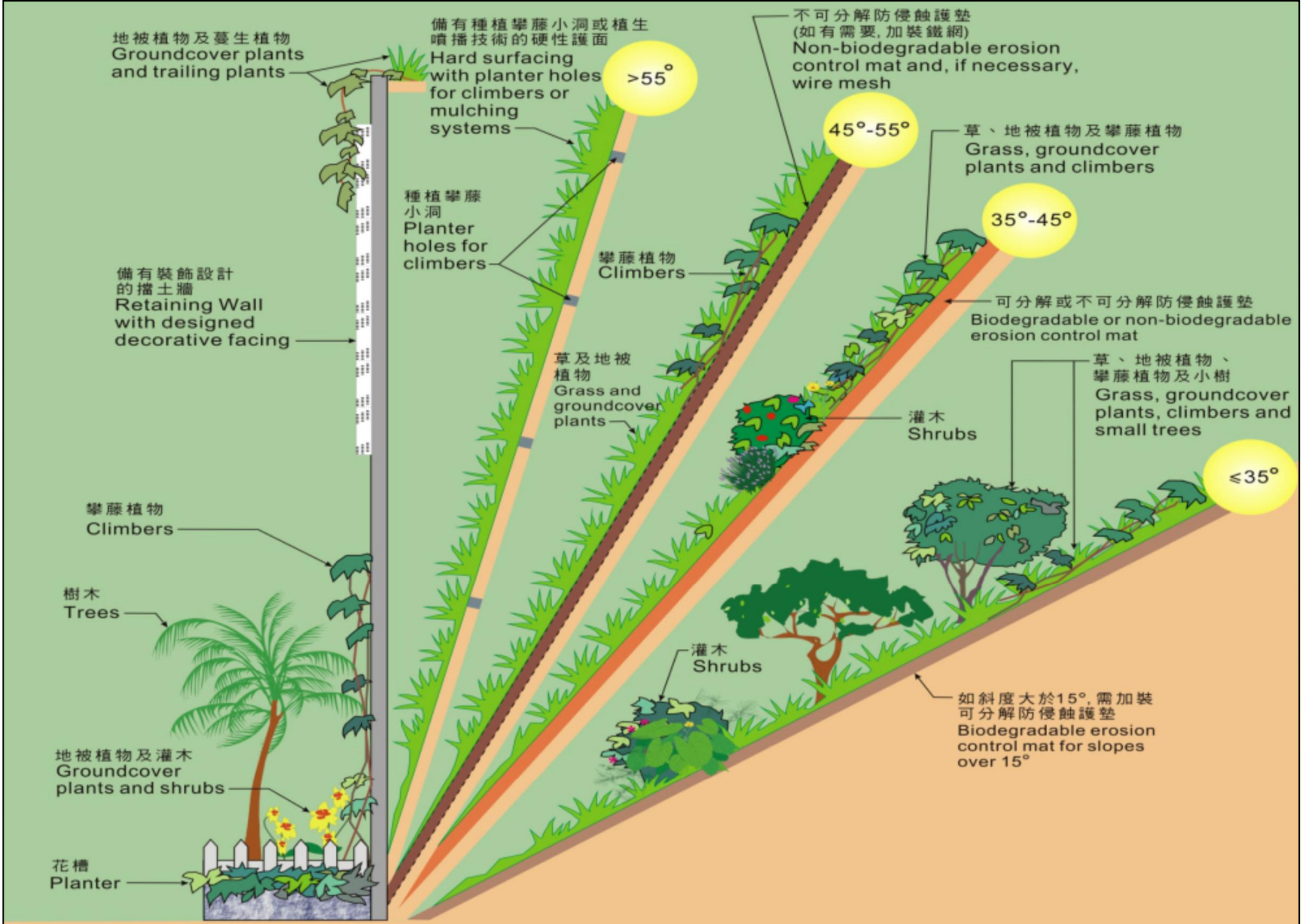
Greening on highway structures 綠化公路結構

(Source: Highway Department, HK)

Greening on slopes 斜坡上綠化

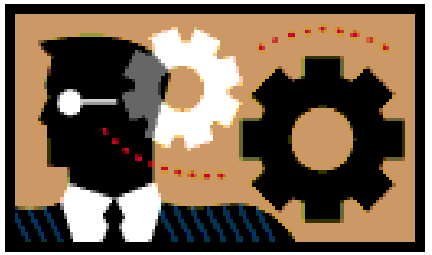


(Source: Civil Engineering and Development Department)



(Source: Civil Engineering and Development Department)

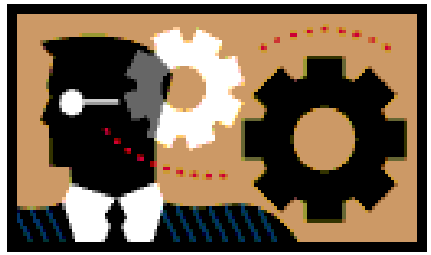
Major considerations
主要考慮因素



- 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

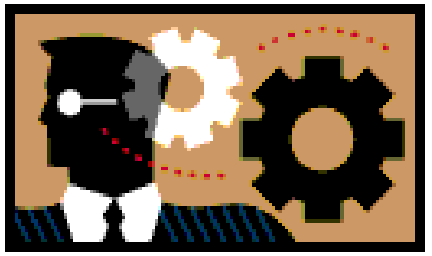
- Other design considerations 其他設計考慮
  - Selection of plants (e.g. hardy plants) 選擇植物
  - Stakeholders' involvement & support 參與支持

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

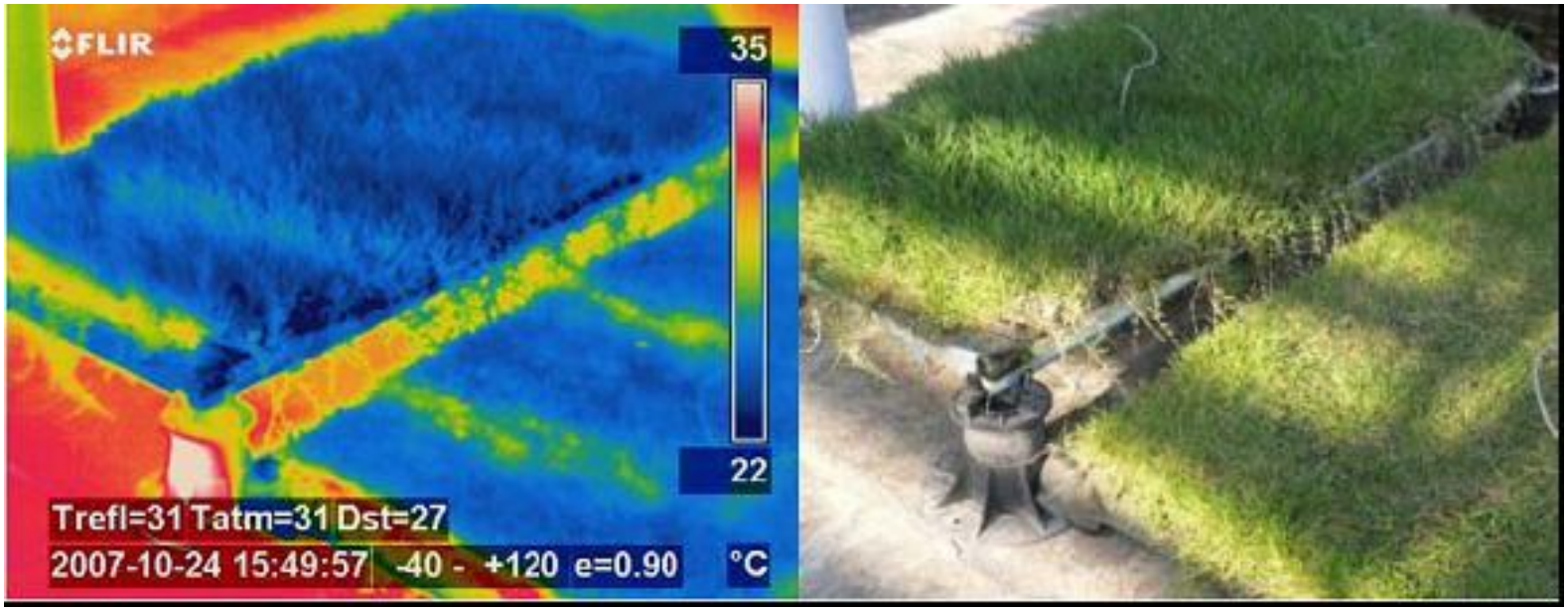
Major considerations
主要考慮因素



- 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.)



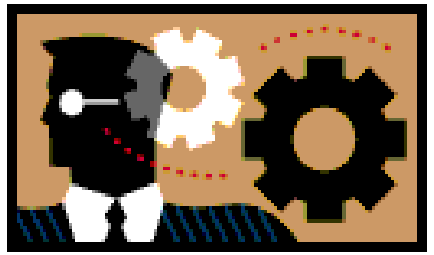
Infrared photo for assessing thermal effects

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

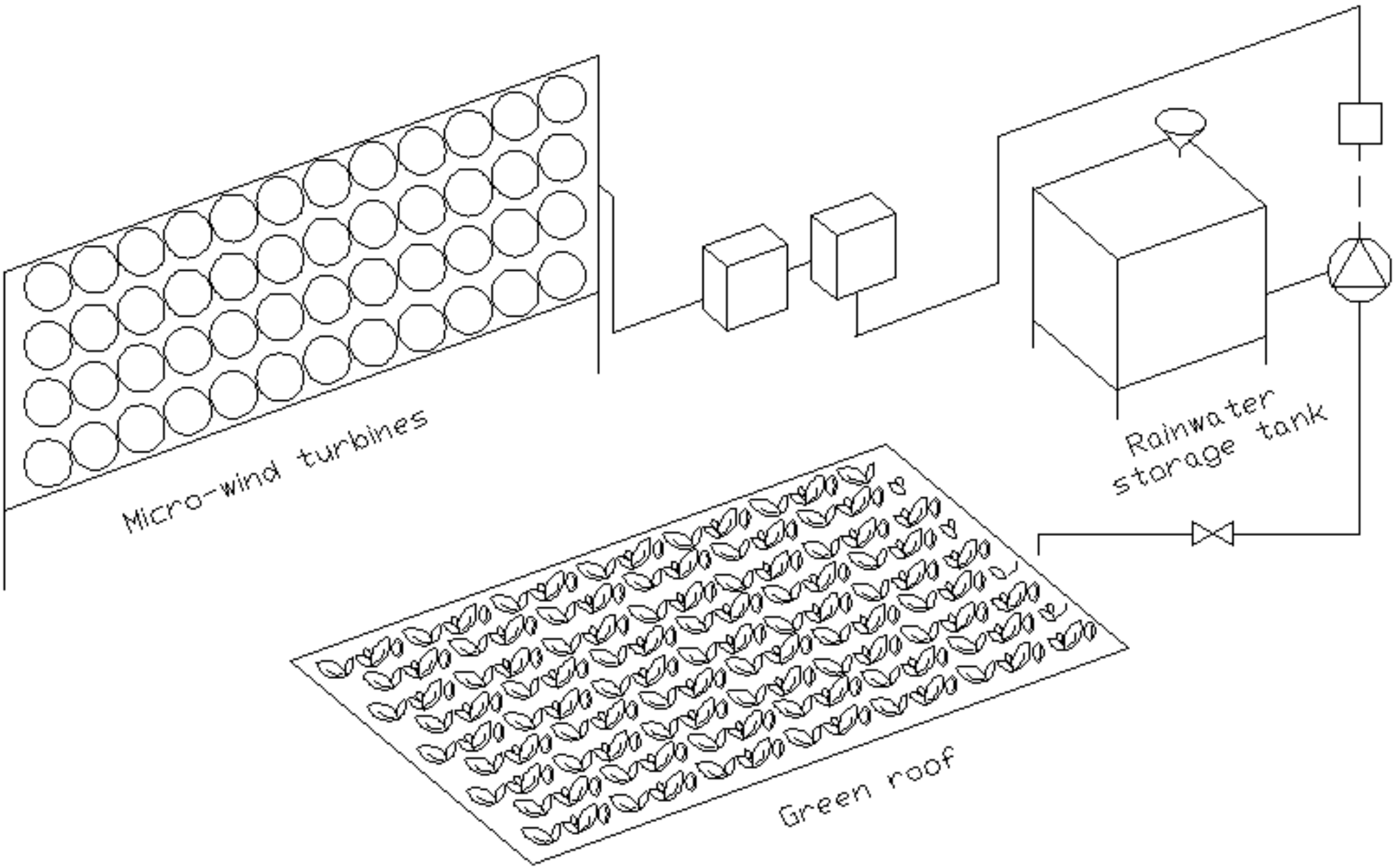


- Costs and commitments 成本和承諾
  - Capital cost (direct & indirect costs) 資本成本(直接和間接成本)
  - Recurrent maintenance costs 經常維修保養費用
  - Life-cycle costs 生命週期成本
  - Risk of failure costs 失敗的風險成本
  - Maintenance commitments 維護承諾
  - Ownership 擁有權

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



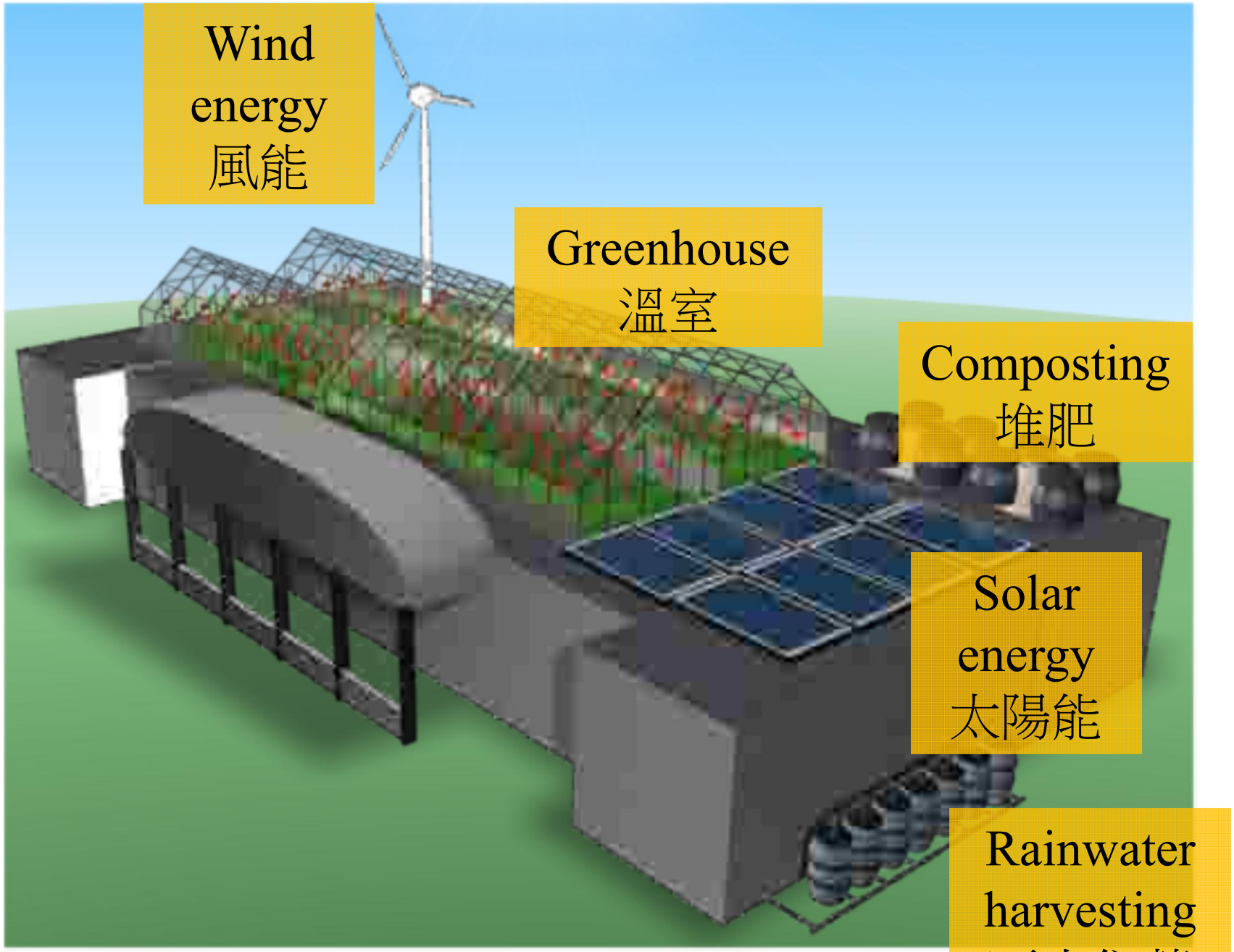
Integration of green roof and solar energy systems
綠色屋頂和太陽能系統的整合

(Source: www.zinco.de)

Integration of green roof and solar energy systems
綠化屋頂和太陽能系統的整合

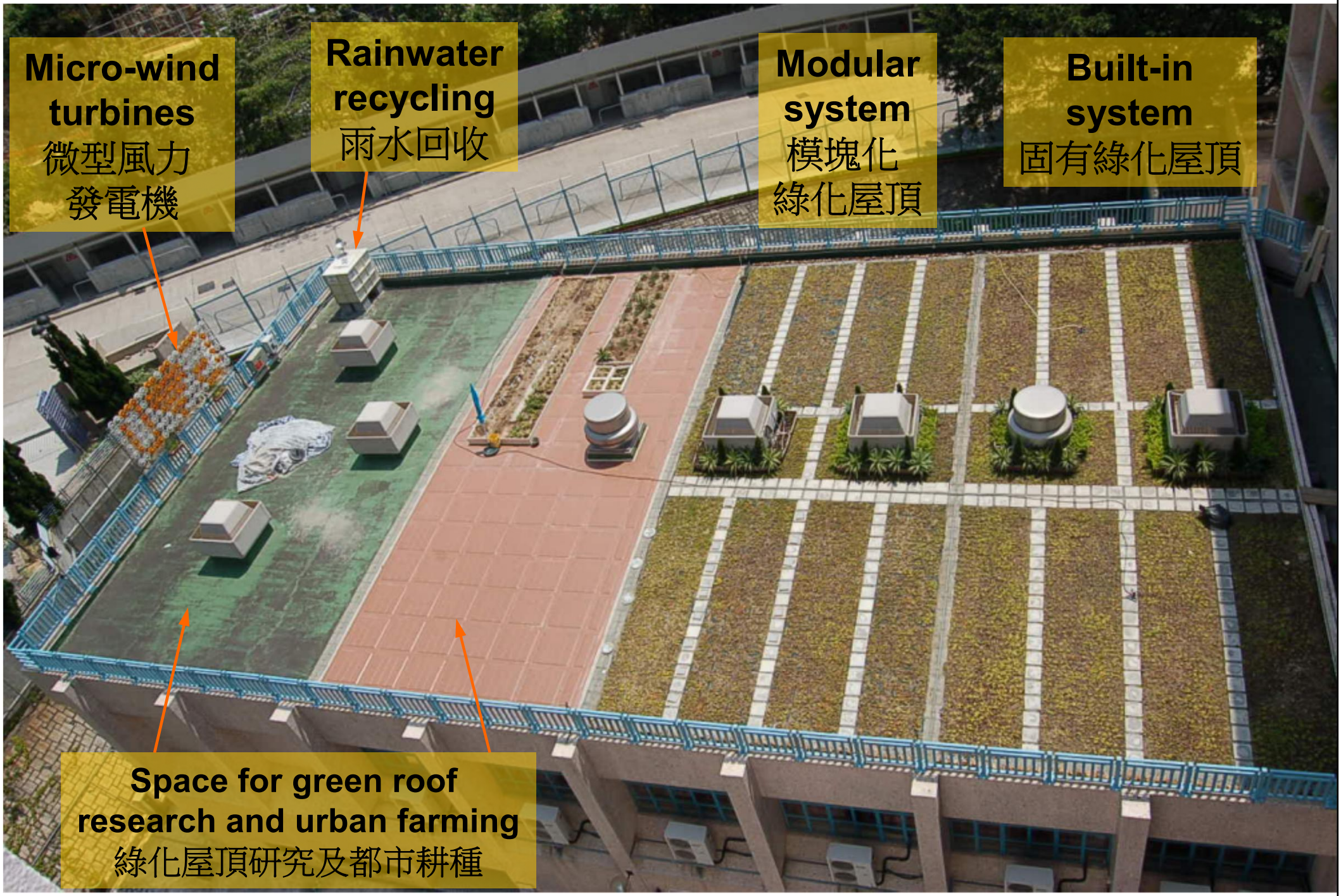
(Photos taken by Dr Sam C M Hui)

Sustainable rooftop farming 可持續屋頂耕種



(Source: www.skyvegetables.com)

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

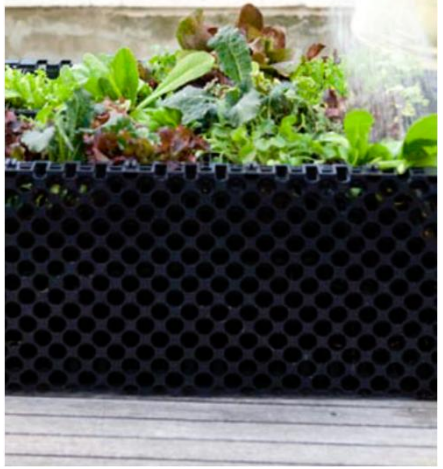
Vegetables and herbal plants
蔬菜和草本植物

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



(Source: www.lifeisagarden.com.au)

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 efforts are needed to determine suitable technologies and policy for promoting them 需要更多的努力，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://ibse.hk/greenroof/)