

Green building and green roof systems in subtropical climate

亞熱帶氣候的綠色建築和屋頂綠化系統



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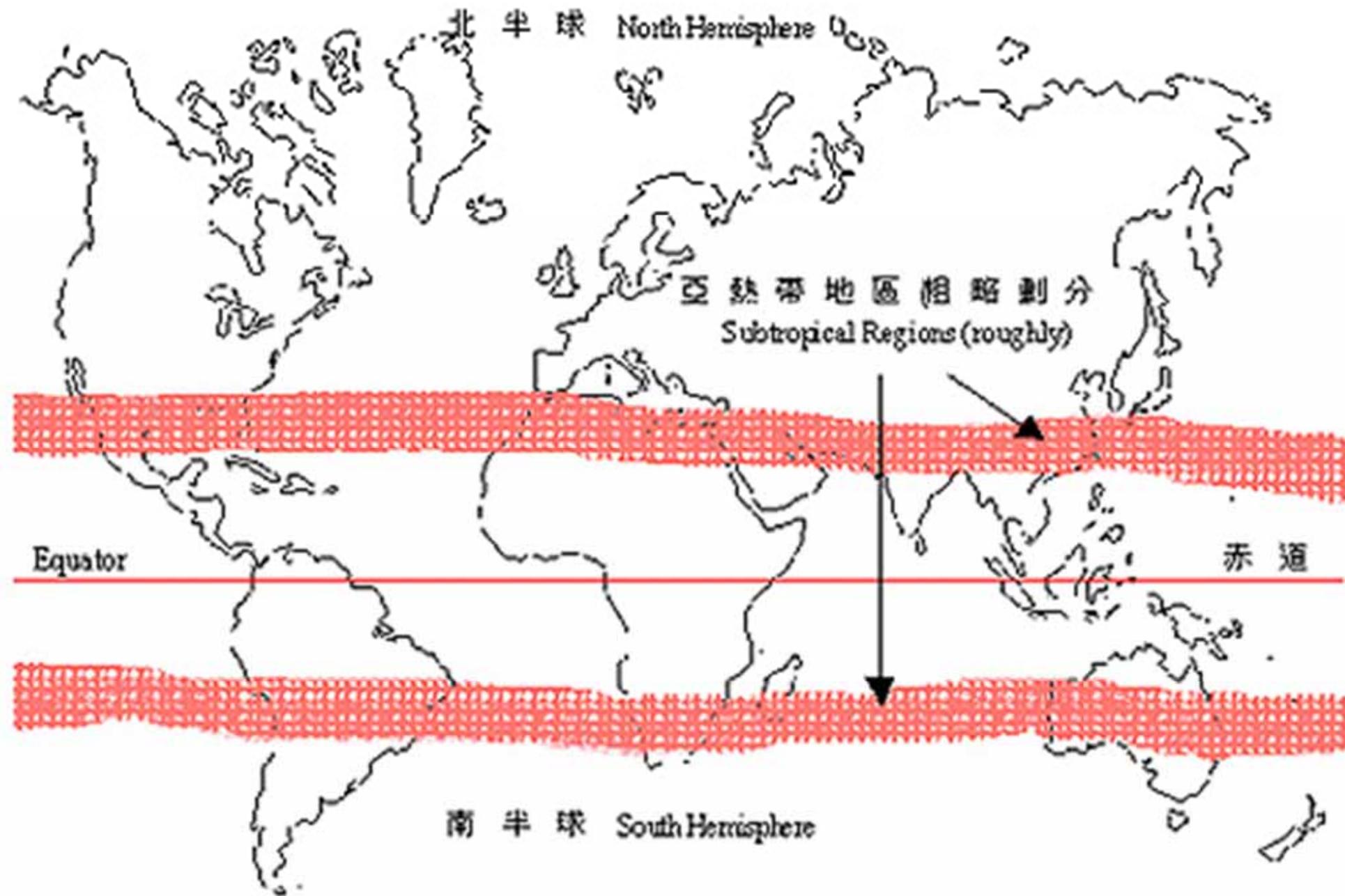
香港大學機械工程系 許俊民博士

Contents 內容



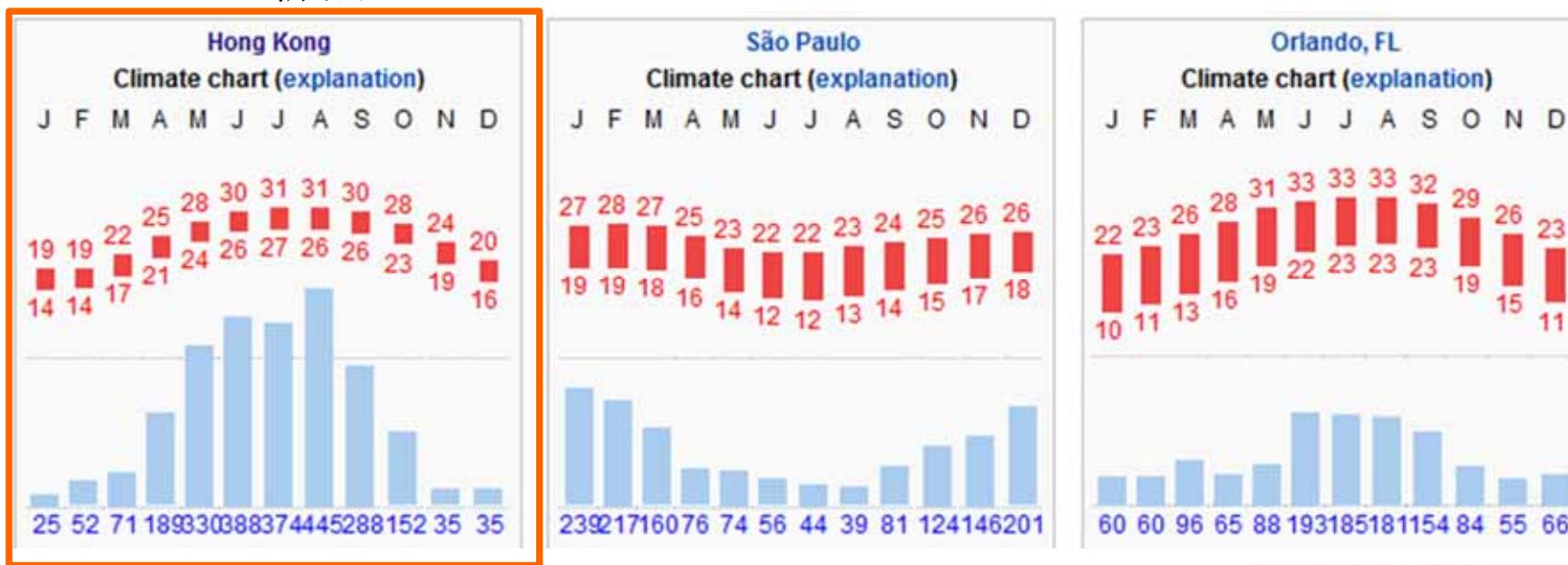
- Subtropical climate 亞熱帶氣候
- What is green building 什麼是綠色建築？
- Green roof systems 綠化屋頂系統
- Potential benefits 潛在的好處
- Major considerations 主要考慮因素
- Development trends 發展趨勢
- Conclusions 結論

Subtropical climate 亞熱帶氣候 (~ 23.5-40°N, 23.5-40°S)



Varieties of subtropical climate 亞熱帶氣候的種類

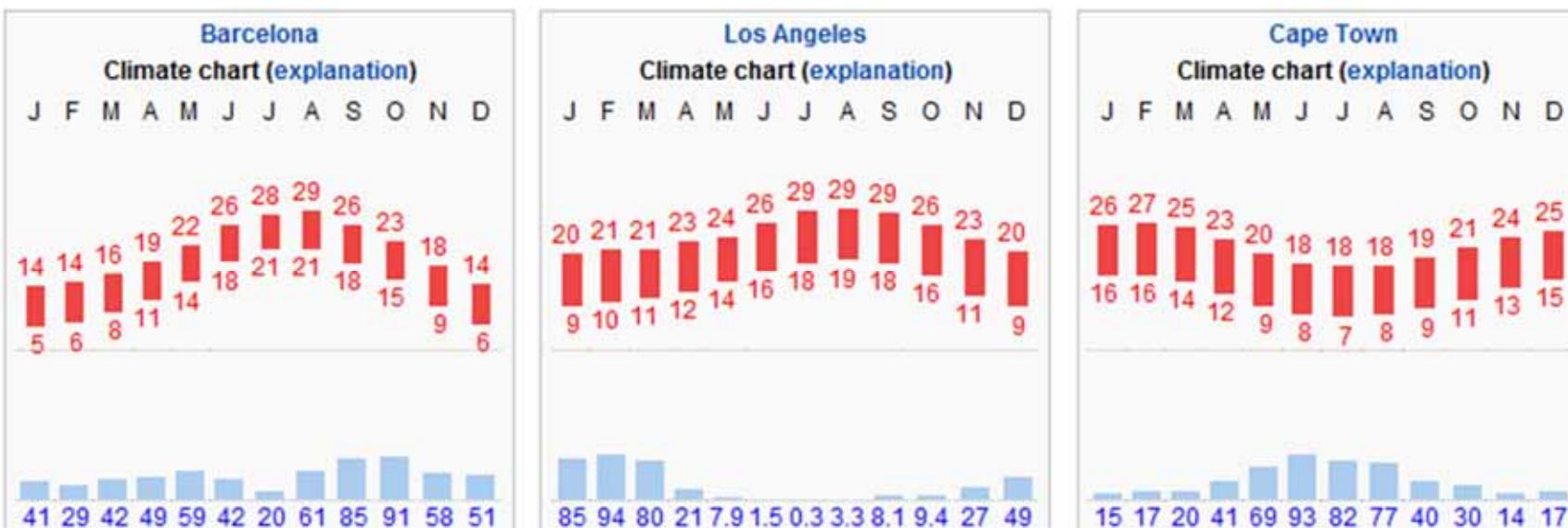
1. Humid 潮濕:



Average max. and min. temperatures in °C

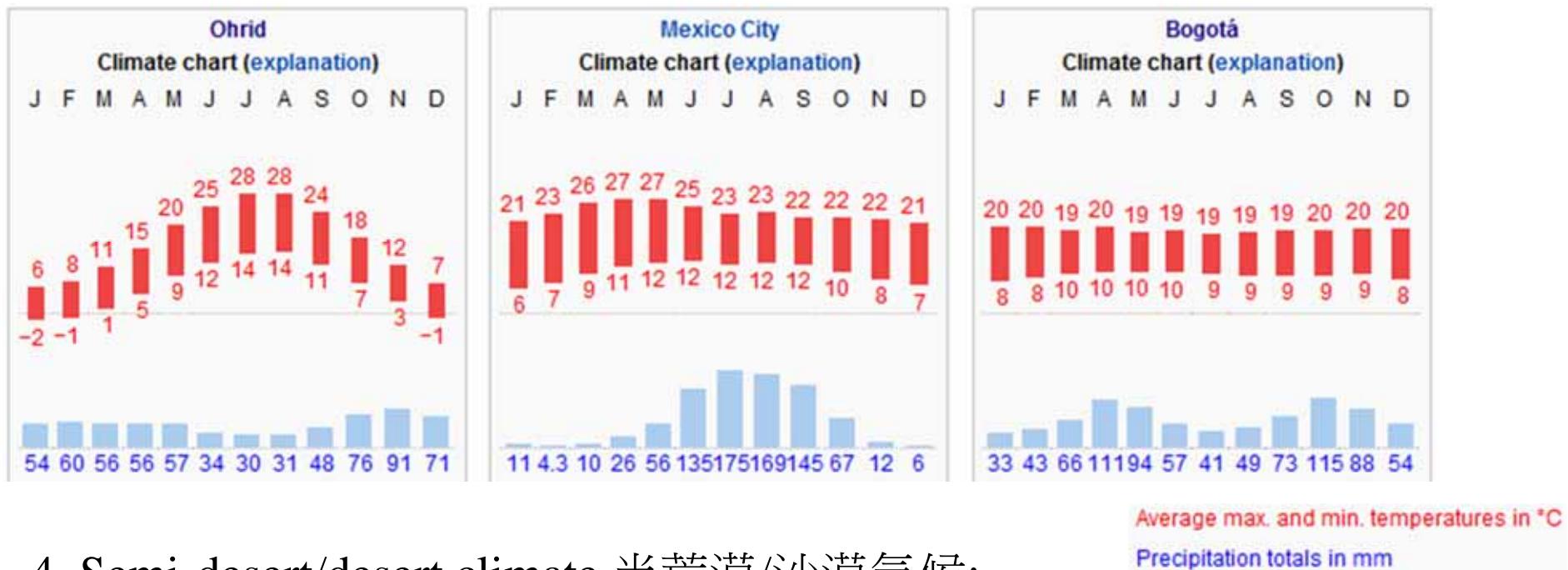
Precipitation totals in mm

2. Mediterranean 地中海:

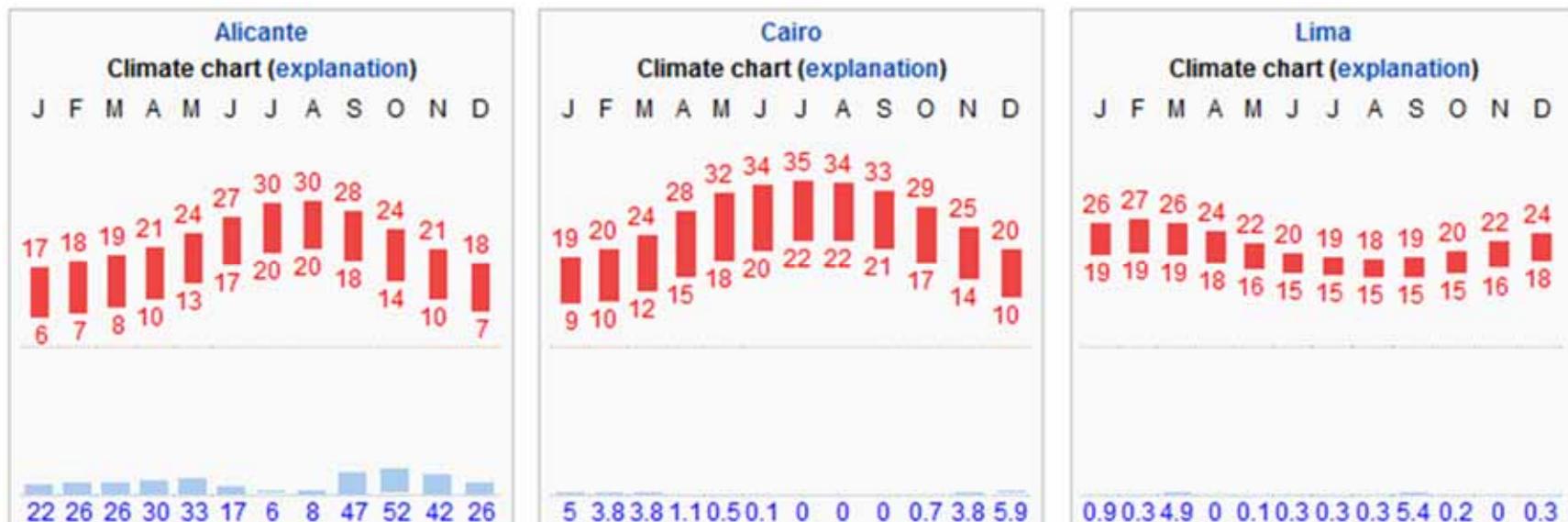


Varieties of subtropical climate 亞熱帶氣候的種類 (cont'd)

3. Highland 高地:



4. Semi-desert/desert climate 半荒漠/沙漠氣候:





Kyoto Face House, 1998



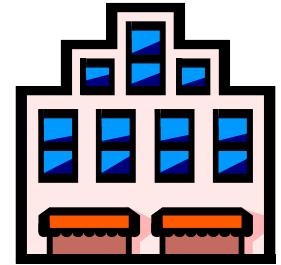
什麼是綠色建築？

“What is
green
building?”



What is green building

什麼是綠色建築？

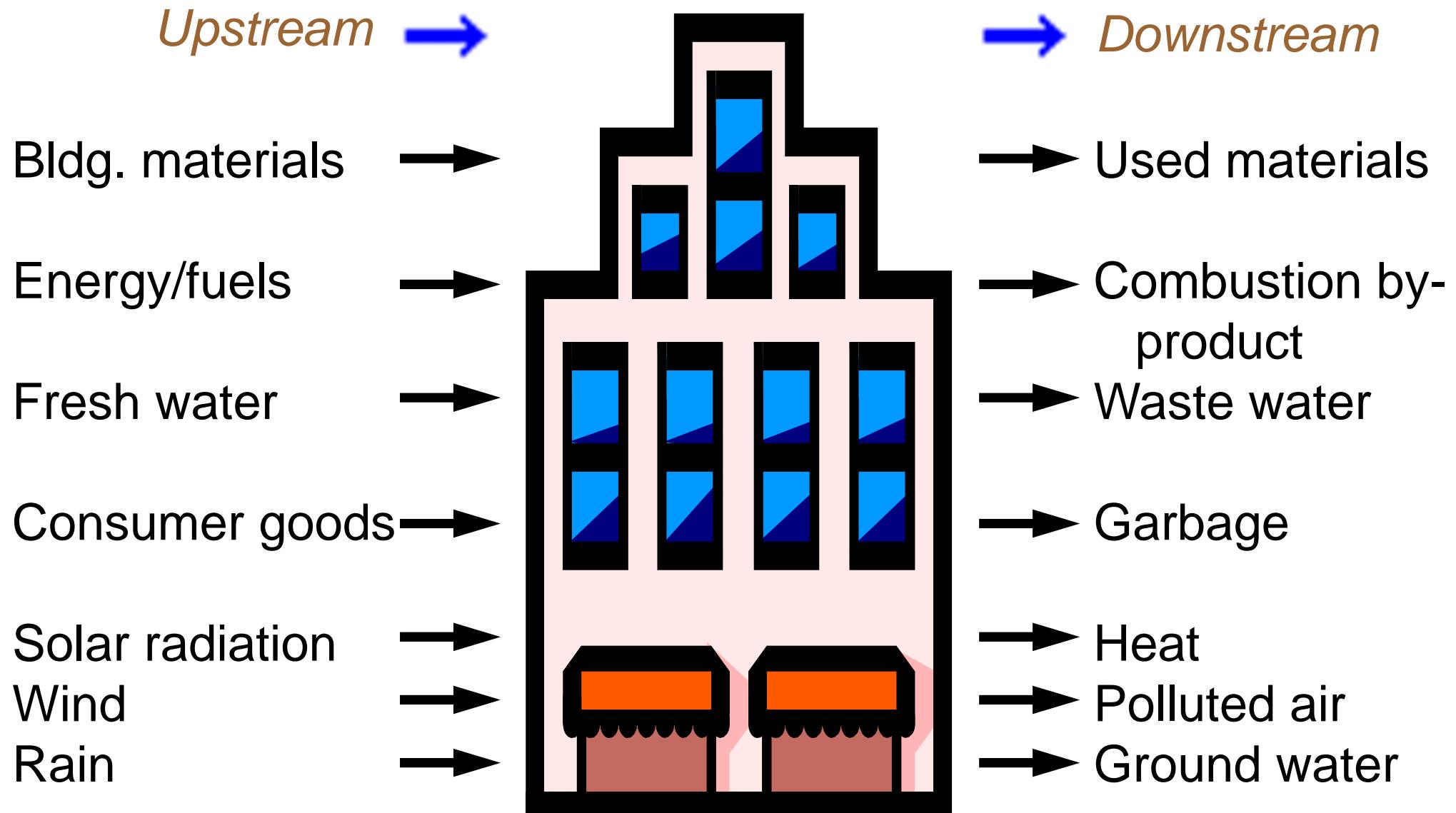


- Green buildings are
 - Energy and resource efficient
 - Non-wasteful and non-polluting
 - Sustainable design that helps minimise broad environmental impacts (e.g. ozone depletion)
 - Highly flexible and adaptable for long-term functionality
 - Easy to operate and maintain (lower running costs)
 - Supportive of the productivity and well-being of the occupants



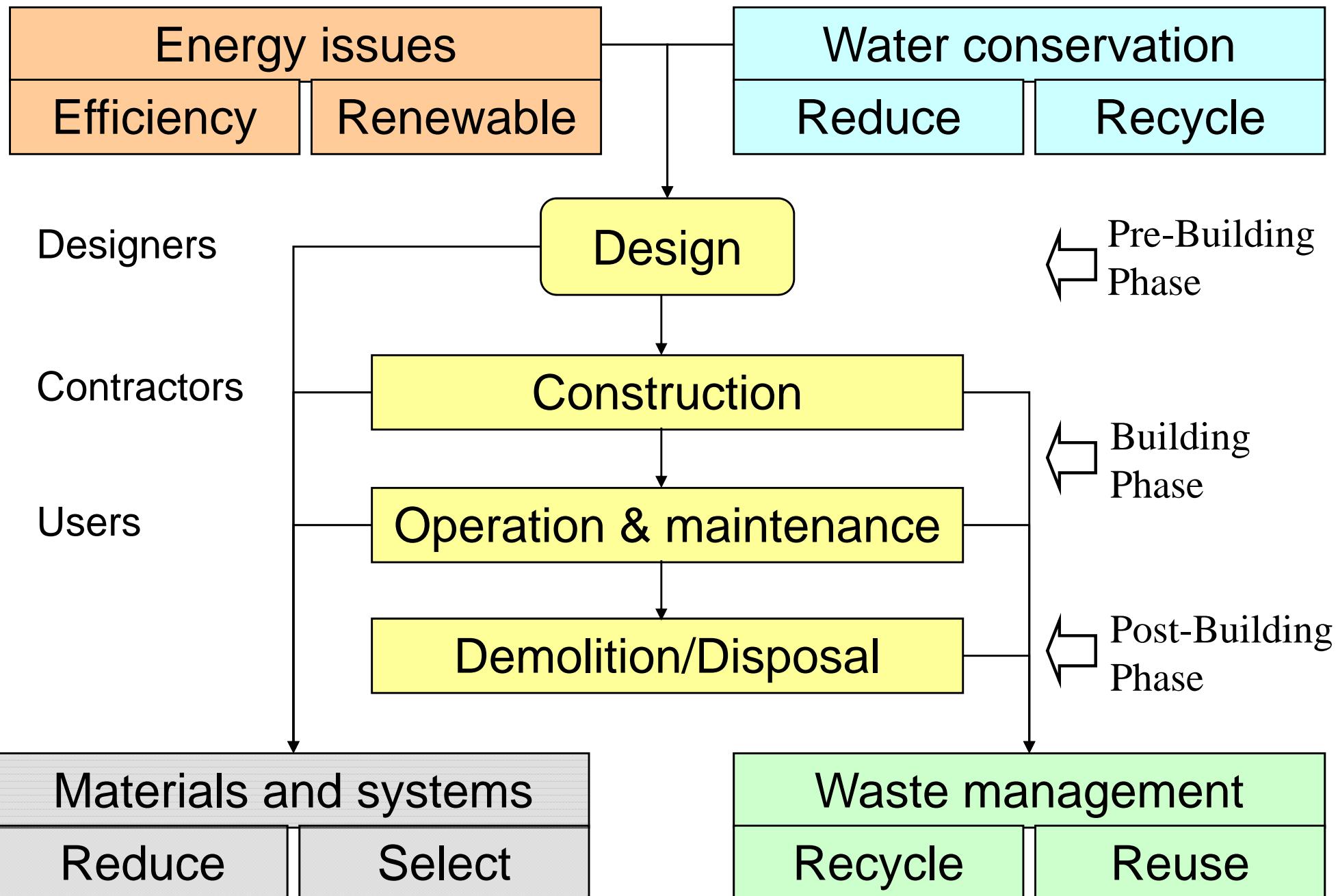
Resource and material flow in the building ecosystem

在建築生態系統的資源與物質流



Building life cycle and sustainable construction

建築生命週期和可持續建造



Green roof systems

綠化屋頂系統



- 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



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



(Photos taken by Dr Sam C M Hui)

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)

Government green roof projects 政府綠化屋頂項目



Sewage treatment plant 污水處理廠

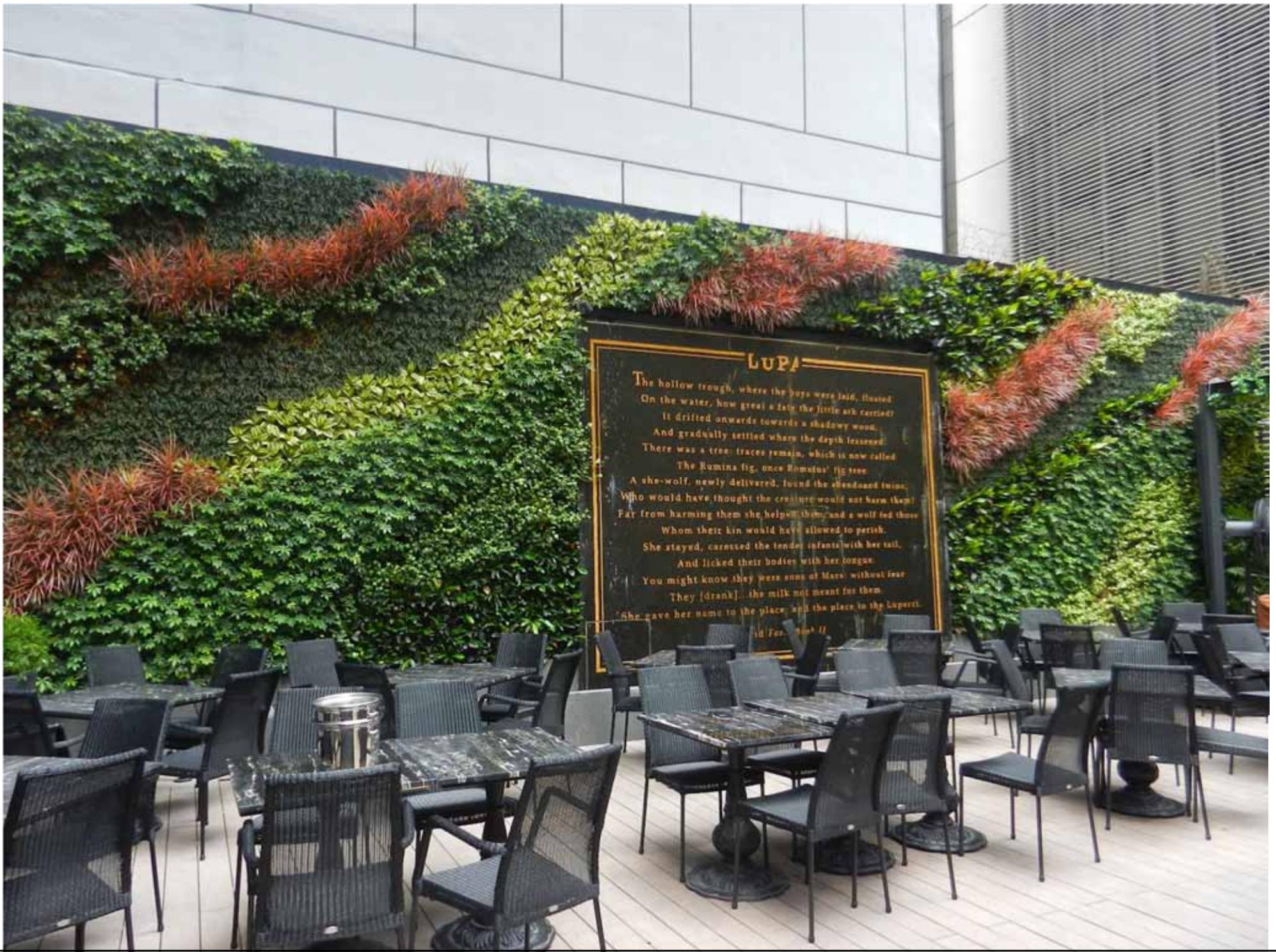


Refuge room 垃圾房

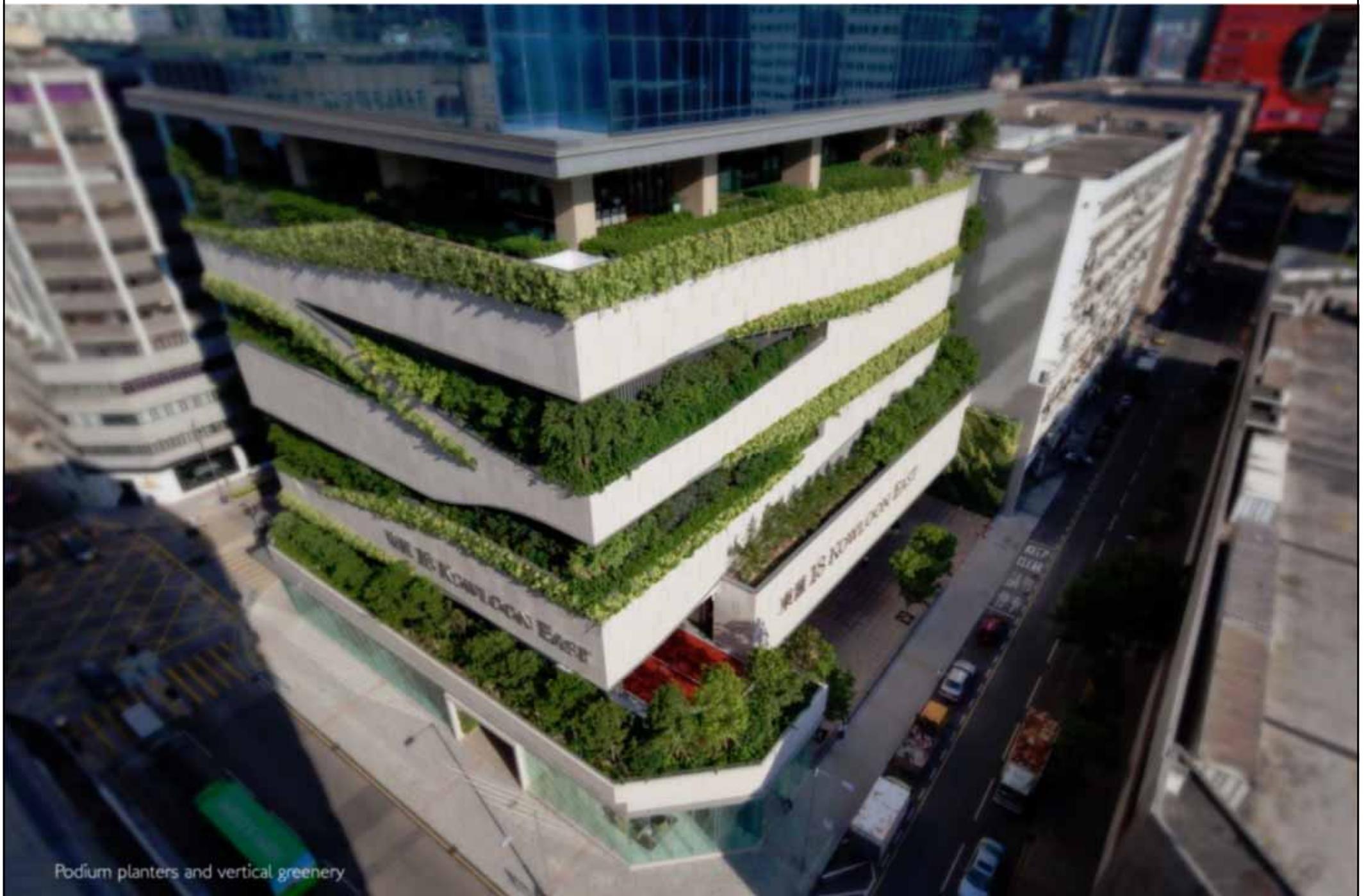


Sewage pumping station
污水泵站

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



Podium planters and vertical greenery

(18 Kowloon East)

Indoor green wall 室內綠化牆

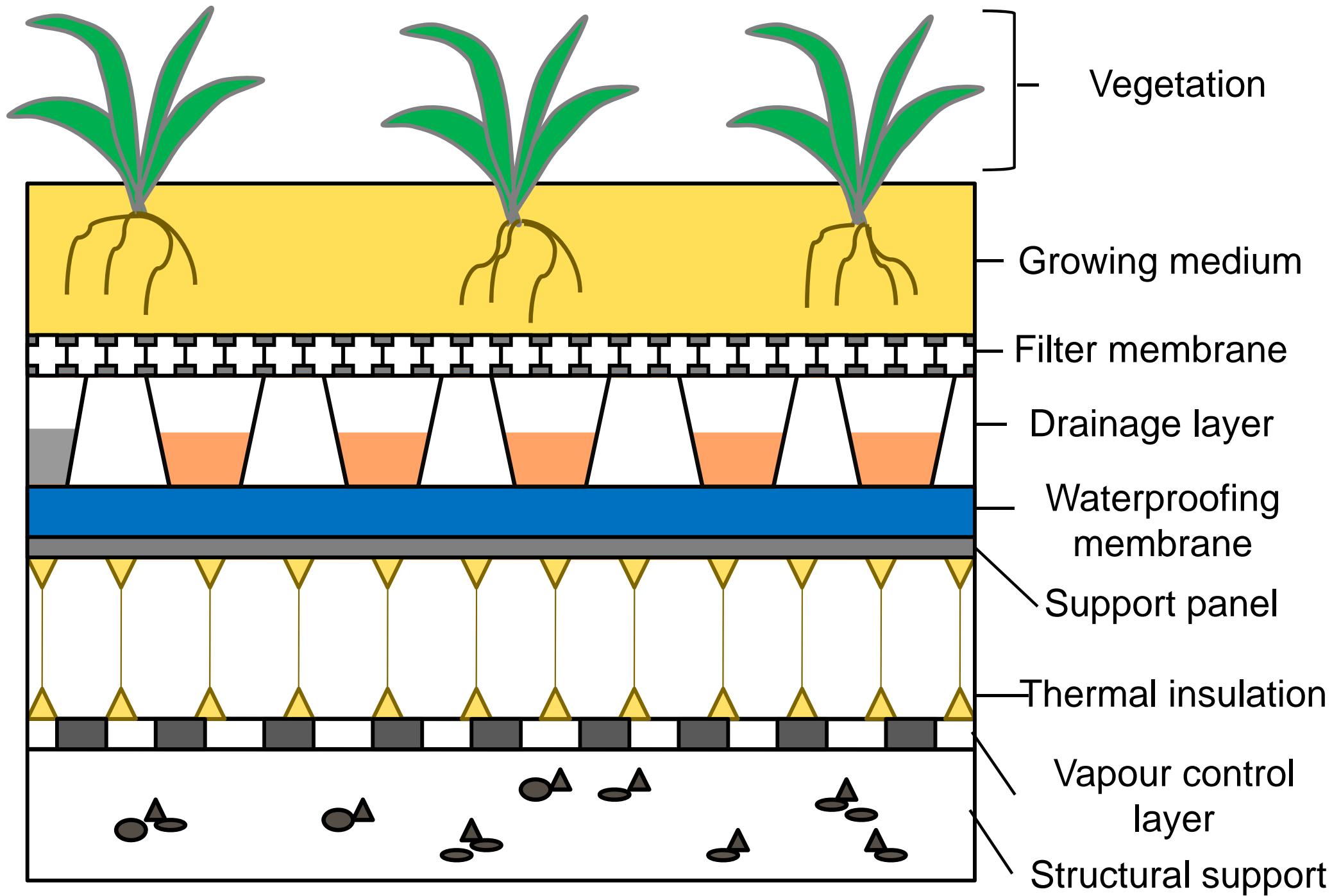


Green roof systems from Germany (left) and Japan (right)
綠化屋頂系統：德國（左）和日本（右）



Typical structure of extensive green roof

粗放型屋頂綠化的典型結構



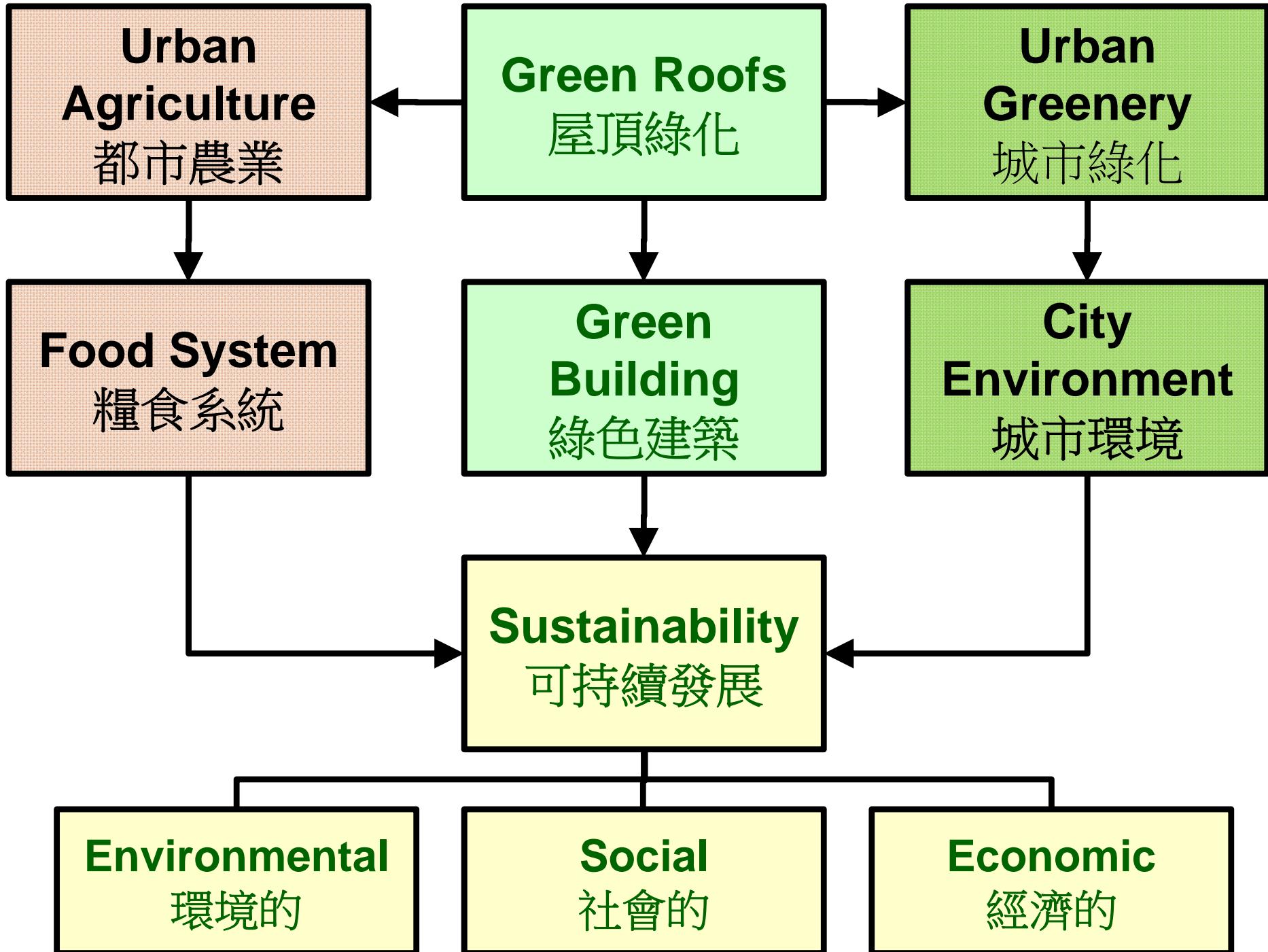
Guidelines for the design and application of green roof systems



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





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



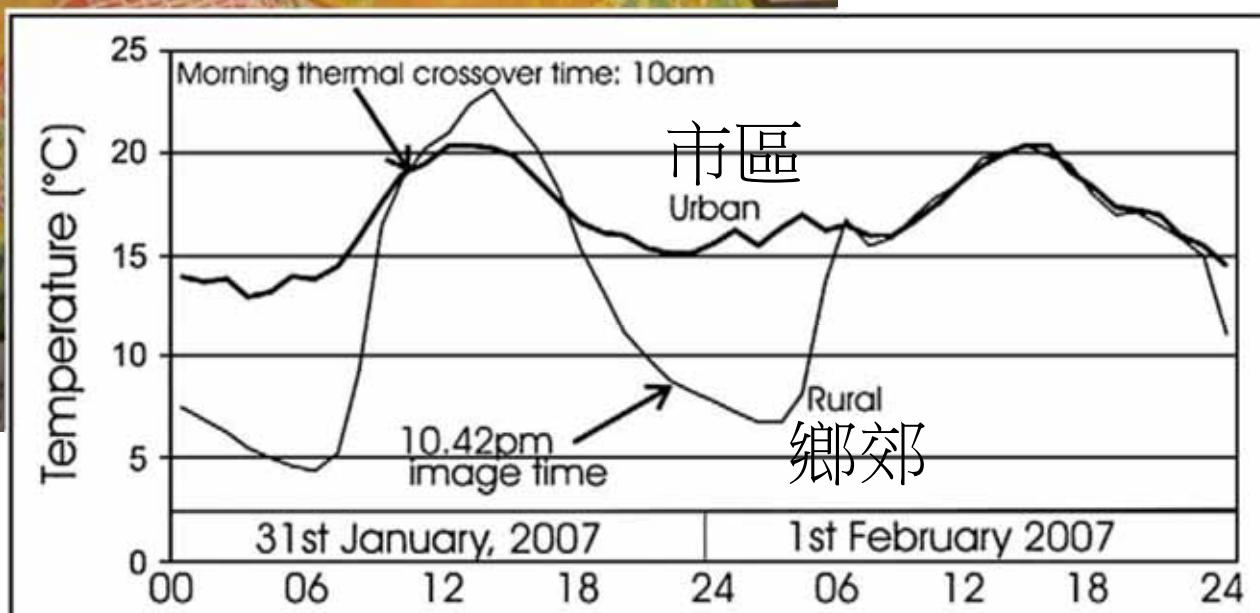
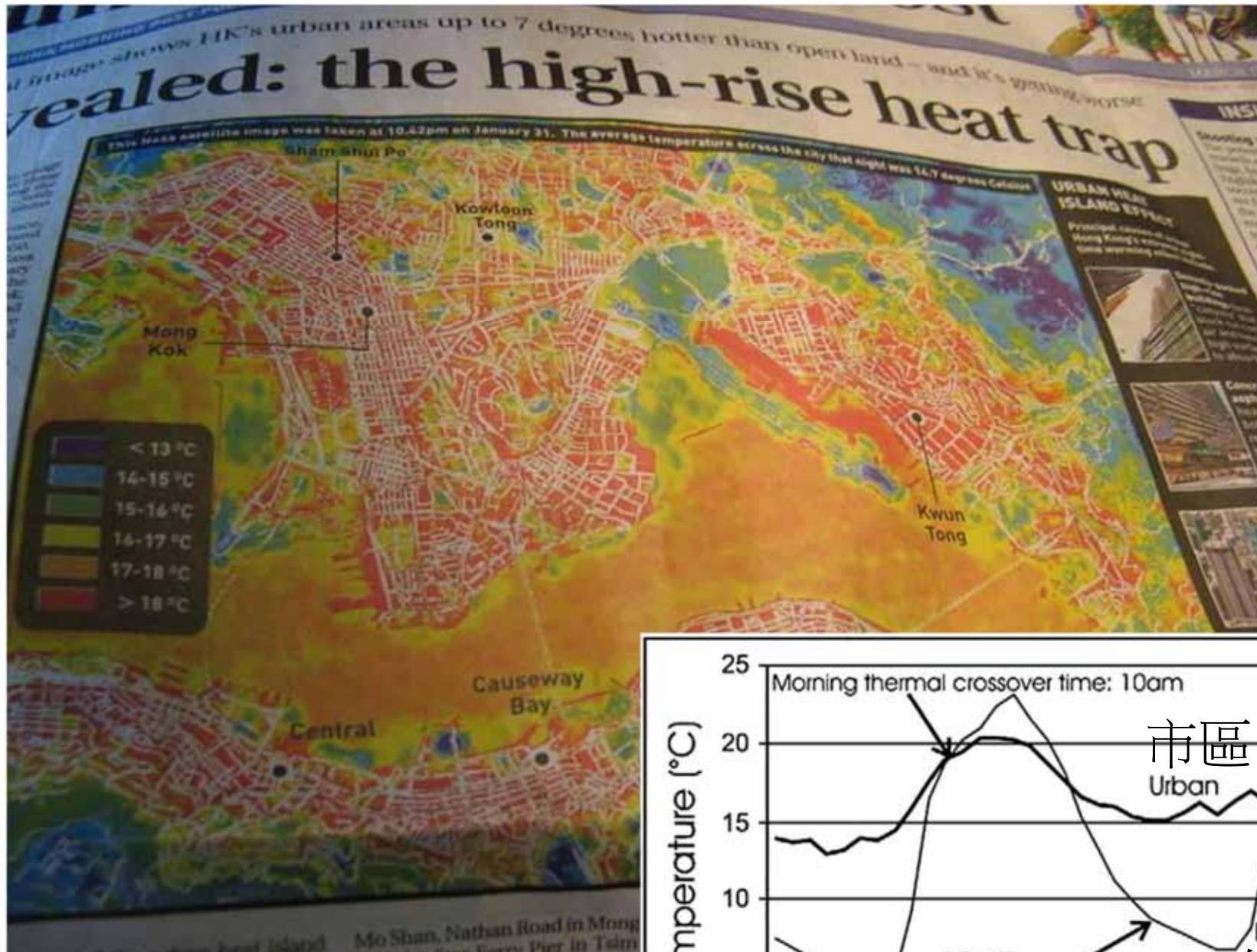


Potential benefits 潛在的好處

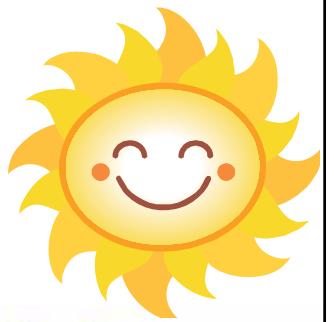
- 1. Environmental benefits: 環境的好處
 - - Mitigate urban heat island 緩解城市熱島
 - - Improve air quality 改善空氣質量
 - - Stormwater management 改善城市雨水管理
 - - Create natural habitat 建立自然棲息地
 - - Increase biodiversity 增加生物多樣性
 - - Insulate and absorb sound 隔音和吸音
 - - Possible urban farming 可作都市農業



Urban heat island in Hong Kong 香港城市熱島



(Source: SCMP and Hong Kong Observatory)



Potential benefits 潛在的好處

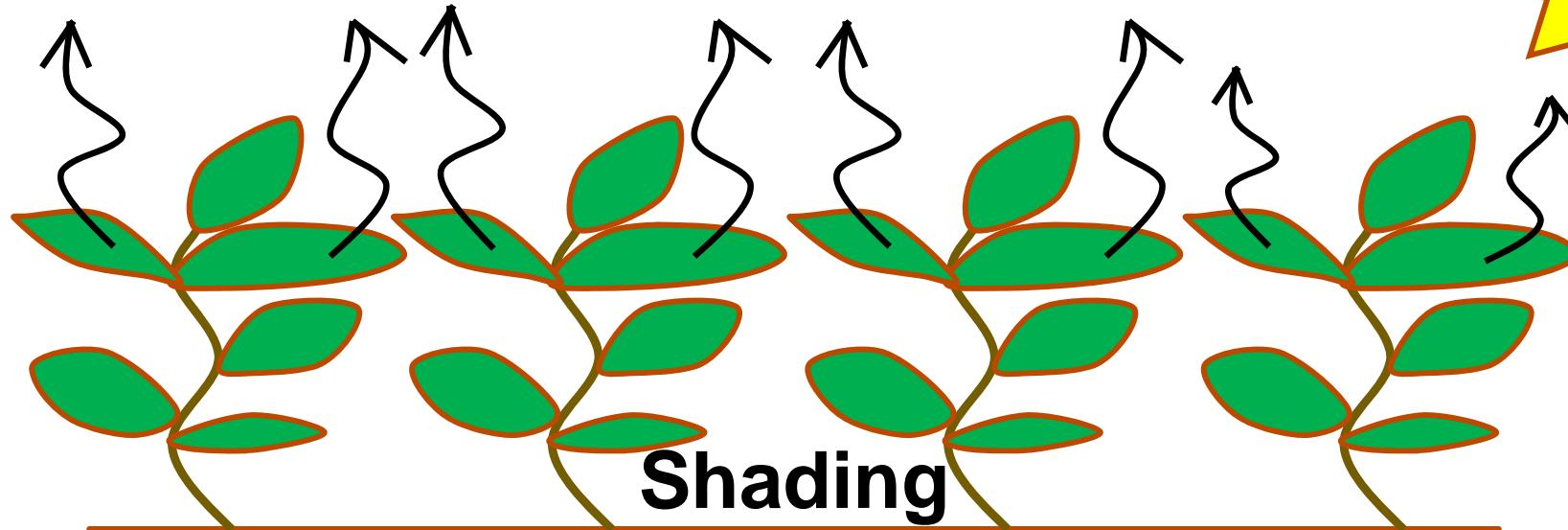
- 2. Economic benefits: 經濟的好處
 - - Improve roof durability 提高屋頂的耐久性
 - - Increase roof material lifetime 增加屋頂的壽命
 - - Reduce building cooling load and energy costs 降低建築冷負荷和能源成本
 - - Provide open space & increase property value 提供開放空間，可增加物業價值
 - - Green building credit points & image 綠色建築評估得分和形象



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

Outdoor

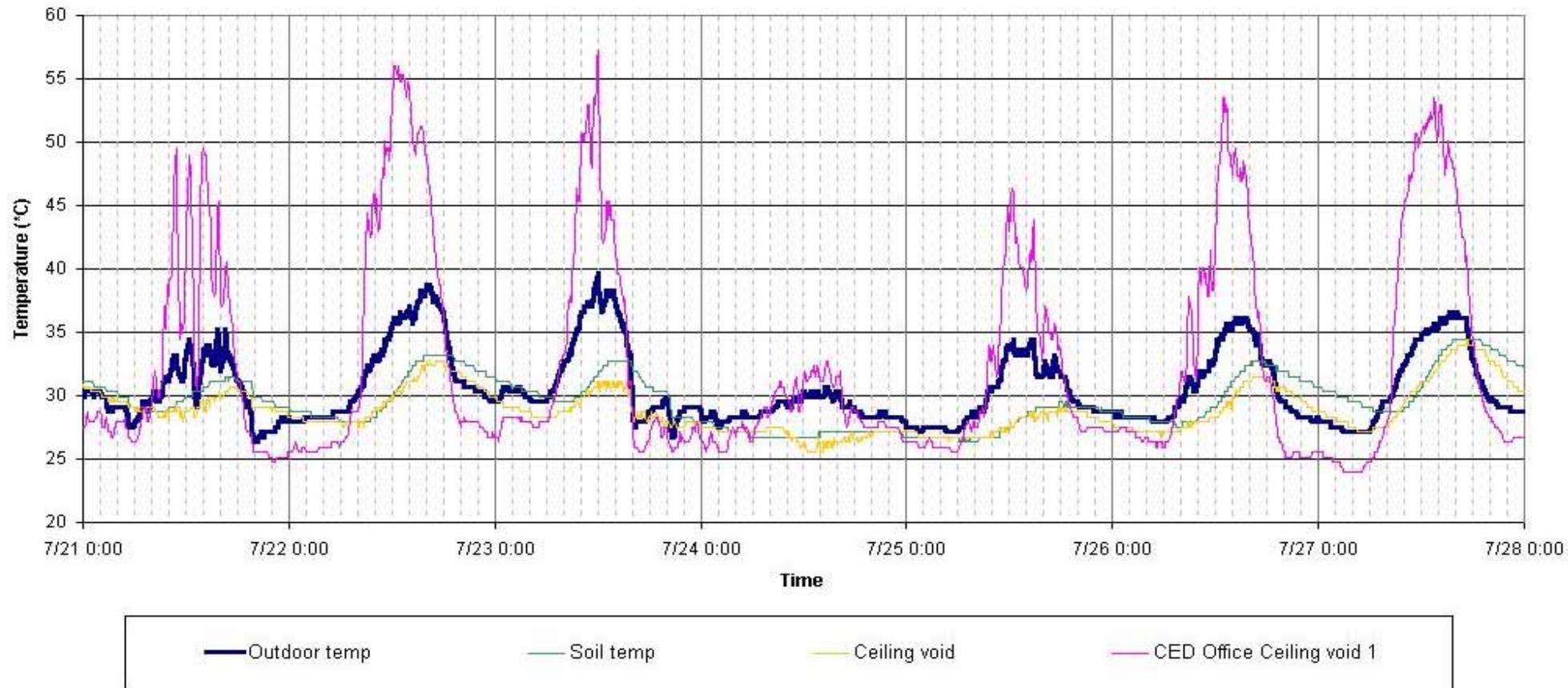
Evapo-transpiration



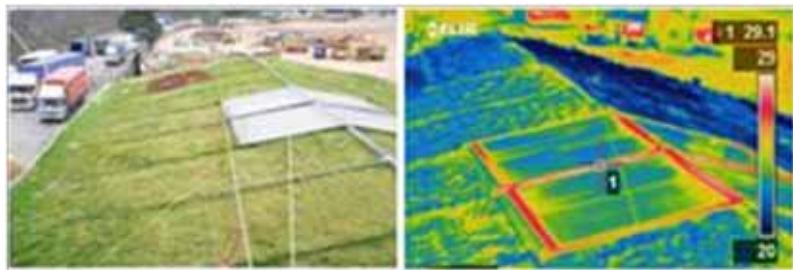
**Insulating
property**

Indoor

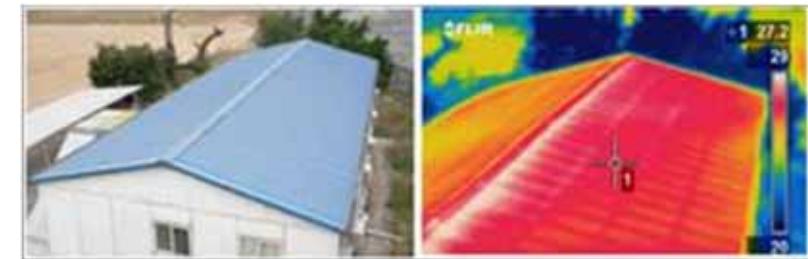
Green roof research at a construction site office in Hong Kong 在香港建築地盤辦事處的屋頂綠化研究



Infrared pictures:

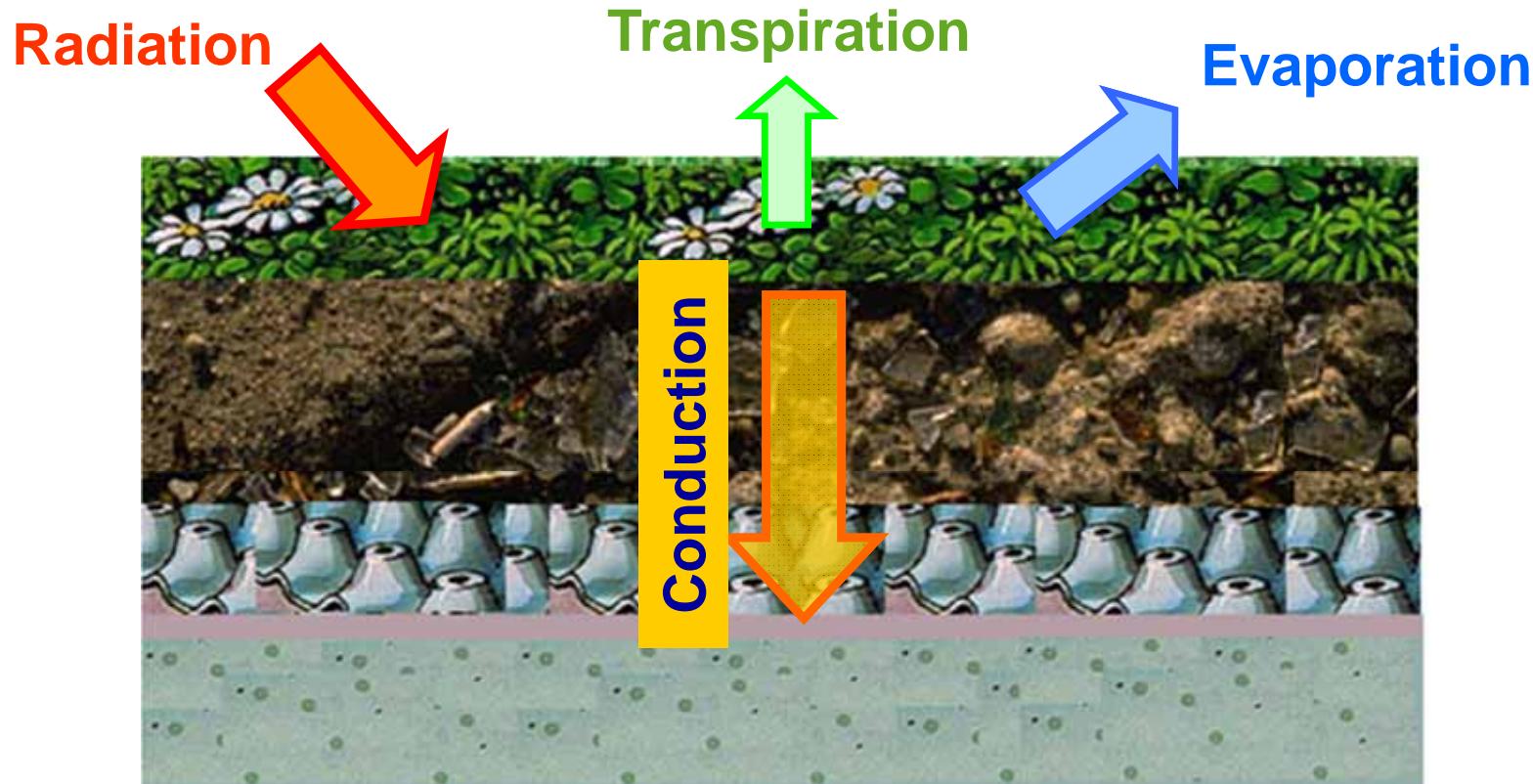


Green roof



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: $q'' = -2LAI \frac{\rho C_p}{\gamma(r_e + r_i)} \left(\frac{wRT}{h_m} \right)$

Conduction:

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



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



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)

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



(Source: Ng Yuk Secondary School)

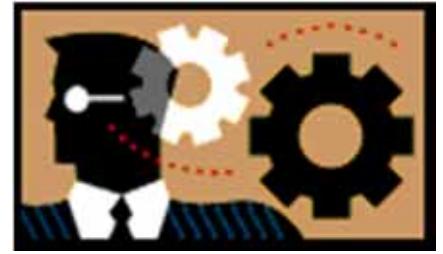
School education green roof project 學校教育屋頂綠化工程



(Source: Environment and Conservation Fund)

Major considerations

主要考慮因素

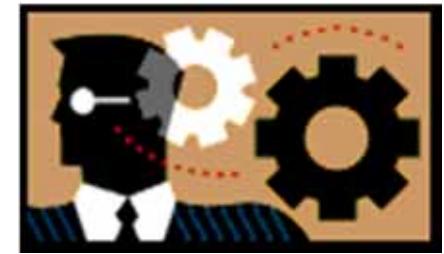


- Key factors for planning 主要規劃因素
 - Structural loading 結構負荷
 - Accessibility 能否容易到達
 - Waterproofing 屋面防漏水
 - Drainage 排水渠務
 - Maintenance 維護保養
- Other design considerations 其他設計考慮
 - Selection of plants (e.g. hardy plants) 選擇植物
 - Stakeholders' involvement & support 參與支持



Major considerations

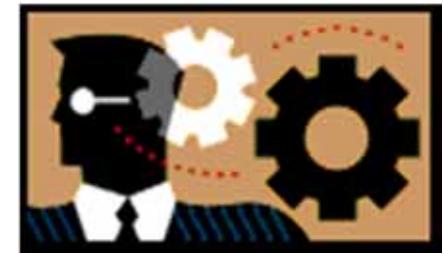
主要考慮因素



- Climatic factors (e.g. HK) 氣候因素 (香港)
 - 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

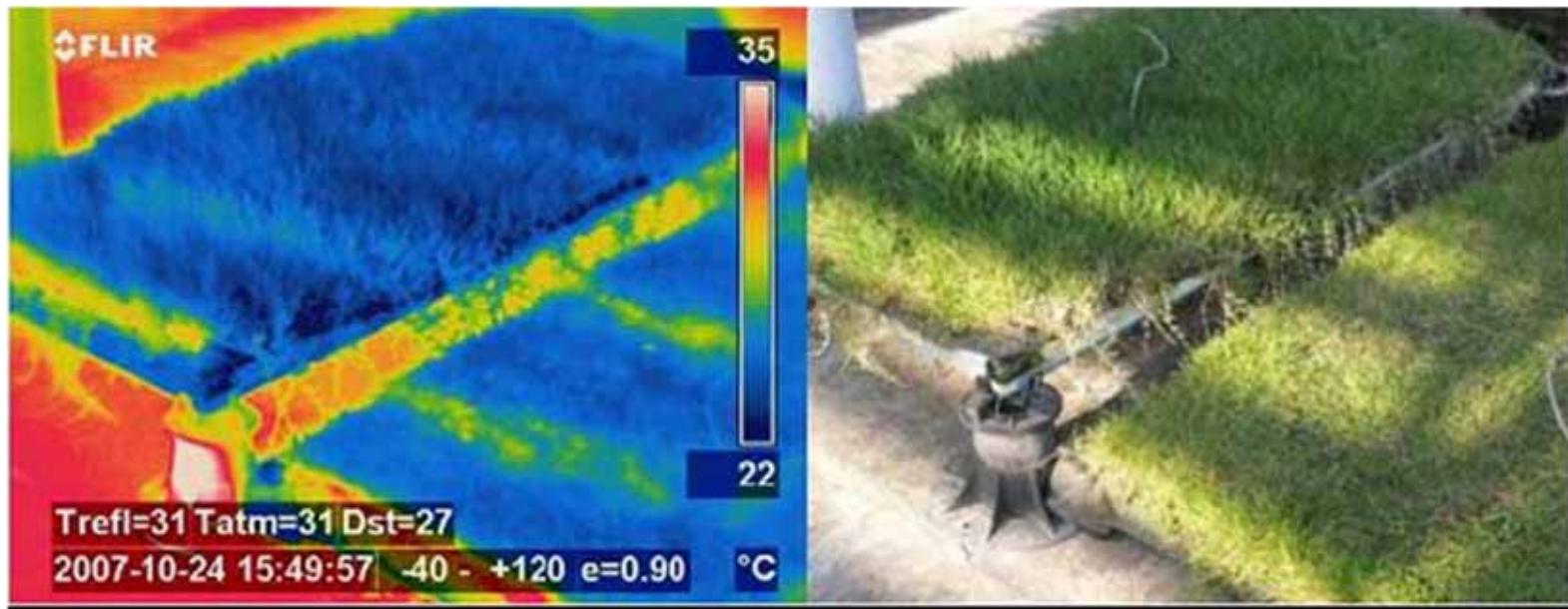


- High-rise buildings: very limited roof spaces
高層建築：屋頂的空間非常有限
 - Better to apply green roofs to medium- or low-rise buildings/structures or podium roofs 更好地適用於中或低矮建築物/構築物或平台屋頂綠化
 - Podium/sky gardens 平台，空中花園
- Structural loading 結構荷載
 - Determine validity and cost 確定有效性和成本
 - For existing buildings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



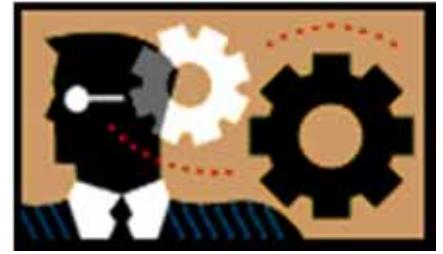
Infrared photo for assessing thermal effects
評估熱效應的紅外照片



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

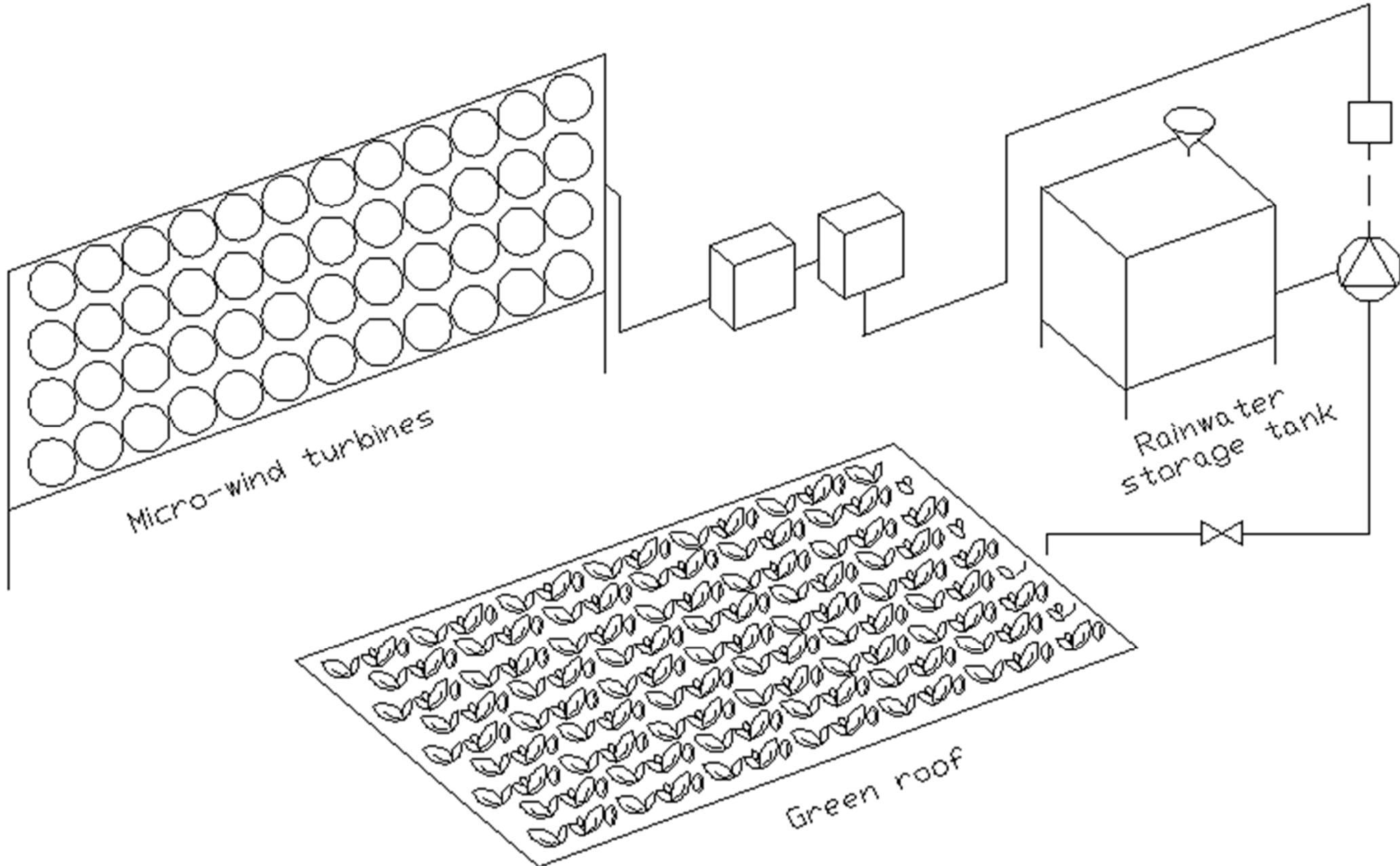


- Sustainable technologies 可持續發展技術
 - Rainwater harvesting 雨水收集
 - Renewable energy (e.g. solar photovoltaic & wind) 可再生能源(如太陽能光伏和風能)
 - Composting (for producing fertilizer) 堆肥(用於生產肥料)
- Farming & food production 農業和食品生產
 - Agricultural green roofs 農業屋頂綠化
 - Edible living walls 可食用的活生牆



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



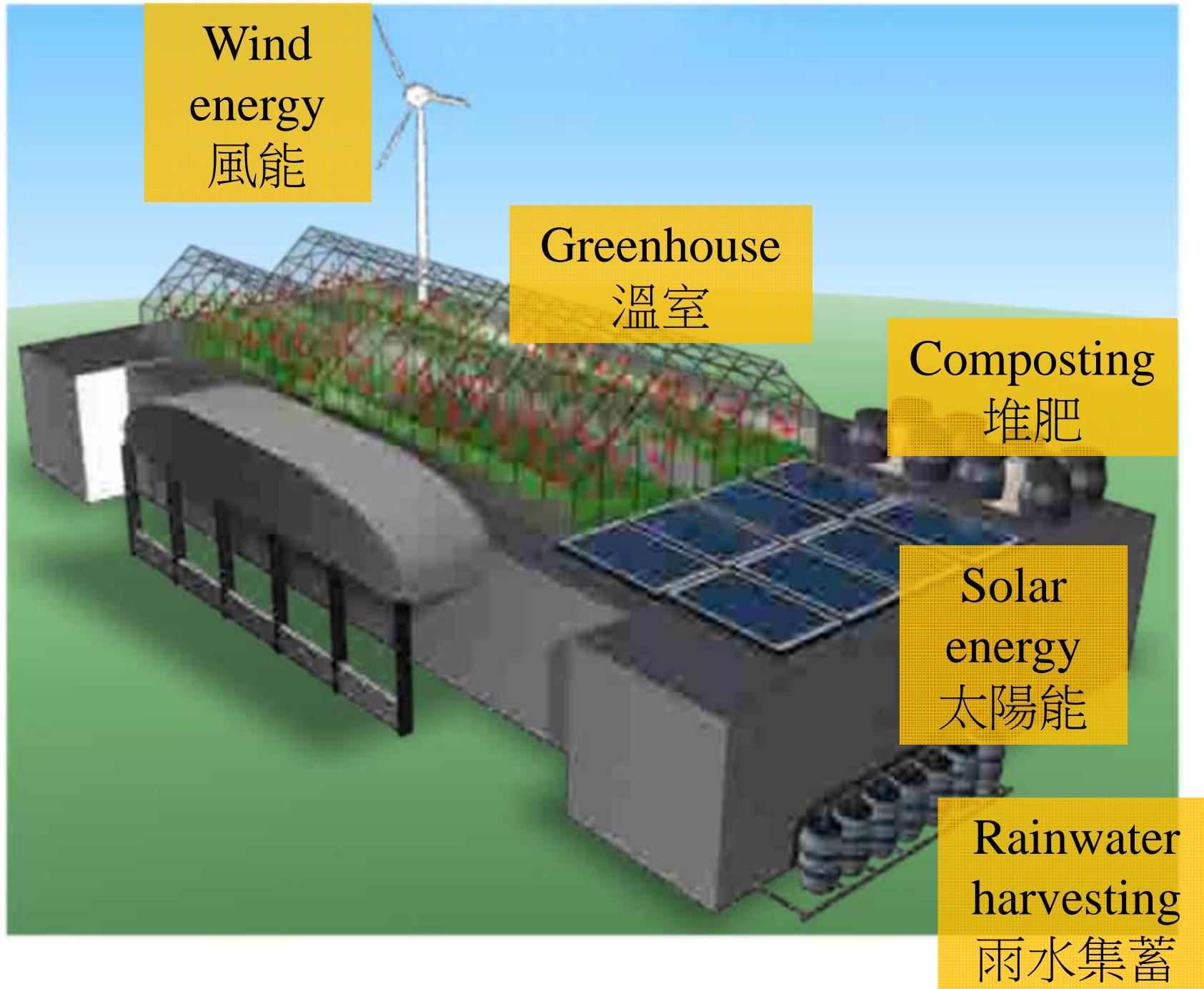
Integration of green roof and solar energy systems

綠色屋頂和太陽能系統的整合

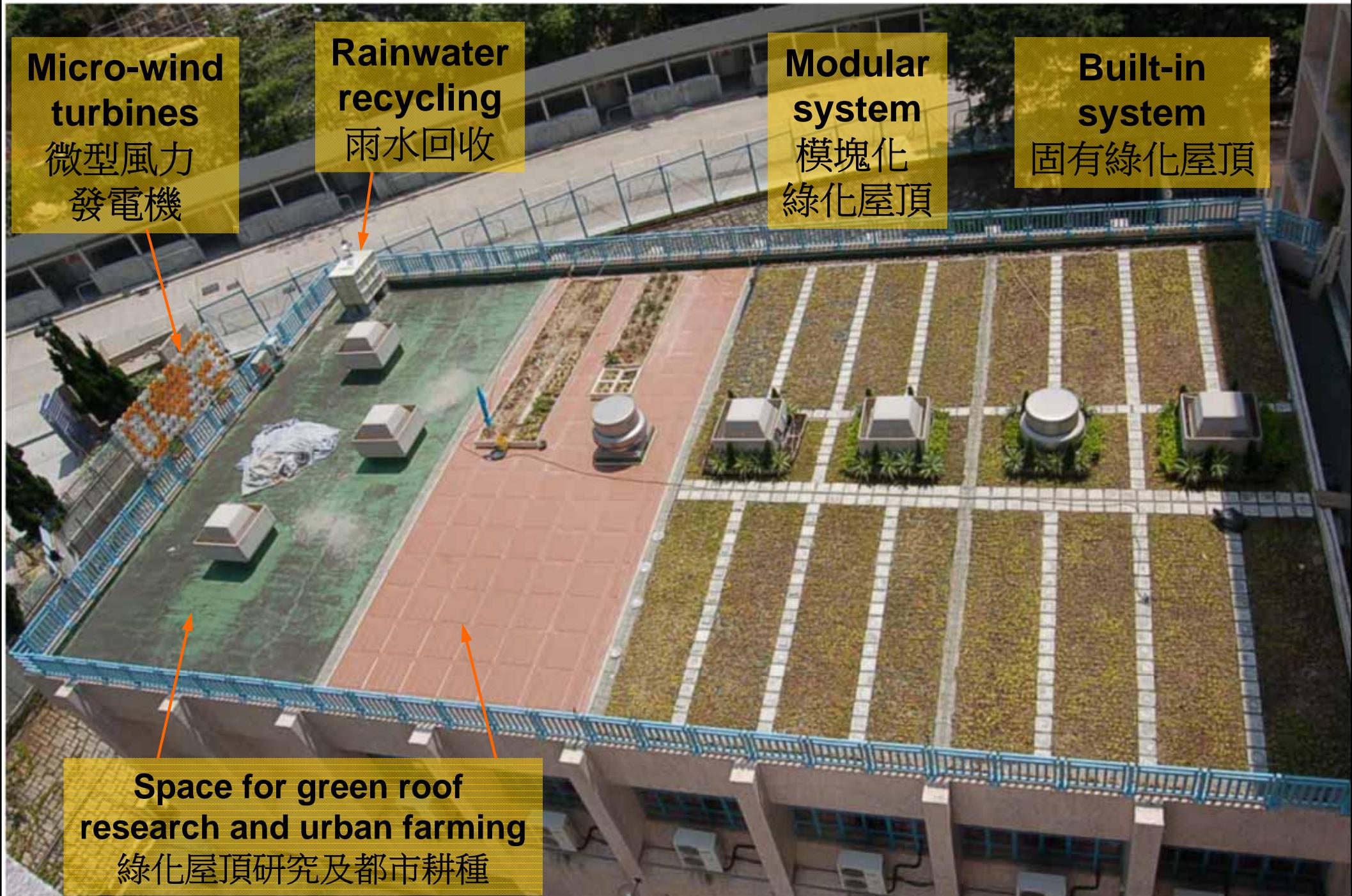


(Source: www.zinco.de)

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

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



Green beans 青豆

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

- Most of the subtropical climate are suitable for vegetation 大部分亞熱帶氣候都適合植被
- Green buildings can integrate vegetation and green roofs for better performance 綠色建築可以結合植物和綠色屋頂有更好的表現
- Need suitable new technologies and policy for promoting urban greening 需要合適的新技術和政策，以促進城市綠化

THANK YOU 謝謝 !!



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