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Green Roofs and Vertical Greening in Hong Kong

香港绿化屋顶和垂直绿化的研究和应用

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Contents 内容

- Introduction 引言
- Potential benefits 潜在的好处
- Green roof examples 屋顶绿化的例子
- Vertical greening examples 垂直绿化的例子
- Major considerations 主要考虑因素
- Development trends 发展趋势
- Conclusions 结论

Hong Kong 香港

Introduction 引言

- Hong Kong Special Administrative Region (HKSAR) 香港特别行政区

  - Land area 土地面积: 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 高建筑密度应付人口增加

  - Urban heat island and lack of greenery space 城市热岛和缺乏绿化空间的问题日益严重

Introduction 引言

- Promote green roofs and vertical greening to achieve urban sustainability 推展绿化屋顶和垂直绿化，实现城市可持续性

- Common types of roof greening: podium gardens and sky gardens 屋顶绿化的常见类型: 平台花园和空中花园
- New greening techniques: 新的绿化技术
  - Extensive green roofs 粗放型屋顶绿化
  - Living walls & green facades 活生墙和绿化墙

A residential podium garden 住宅平台花园

(Photos taken by Dr Sam C M Hui)

Podium garden (Kowloon Station) 平台花园(九龙站)

(Photos taken by Dr Sam C M Hui)

Sky gardens in commercial buildings 在商业大厦的空中花园

(Kowloon Commerce Centre 九龙贸易中心)

(HSBC Building Mongkok 旺角汇丰大厦)

Introduction 引言

- Our research 我们的研究*
  - Started in 2002 从2002年开始
    - 1. Assess the potential & impacts of urban greening评估城市绿化的潜在影响
    - 2. Develop practical guidelines & information 制定切实可行的指引及信息
    - 3. Evaluate building greening policy 评估建筑绿化政策
    - 4. Promote education & technology development 促进教育和科技发展

(* See also http://me.hku.hk/bse/greenroof/)

Introduction 引言

- Examples of previous studies: 以前研究例子
  - Energy and environmental performance of green roofs and living walls 绿化屋顶和活生墙的节能和环保性能
  - Design and assessment of modular green roof systems 模块化屋顶绿化系统的设计与评估
  - Life cycle analysis of green roof urban farming 屋顶绿化都市农业的生命周期分析
  - Feasibility study of green noise barriers 绿化隔音屏障的可行性研究

Green roof research at a construction site office in Hong Kong
在香港建筑地盘办事处的屋顶绿化研究 (2002-2006)

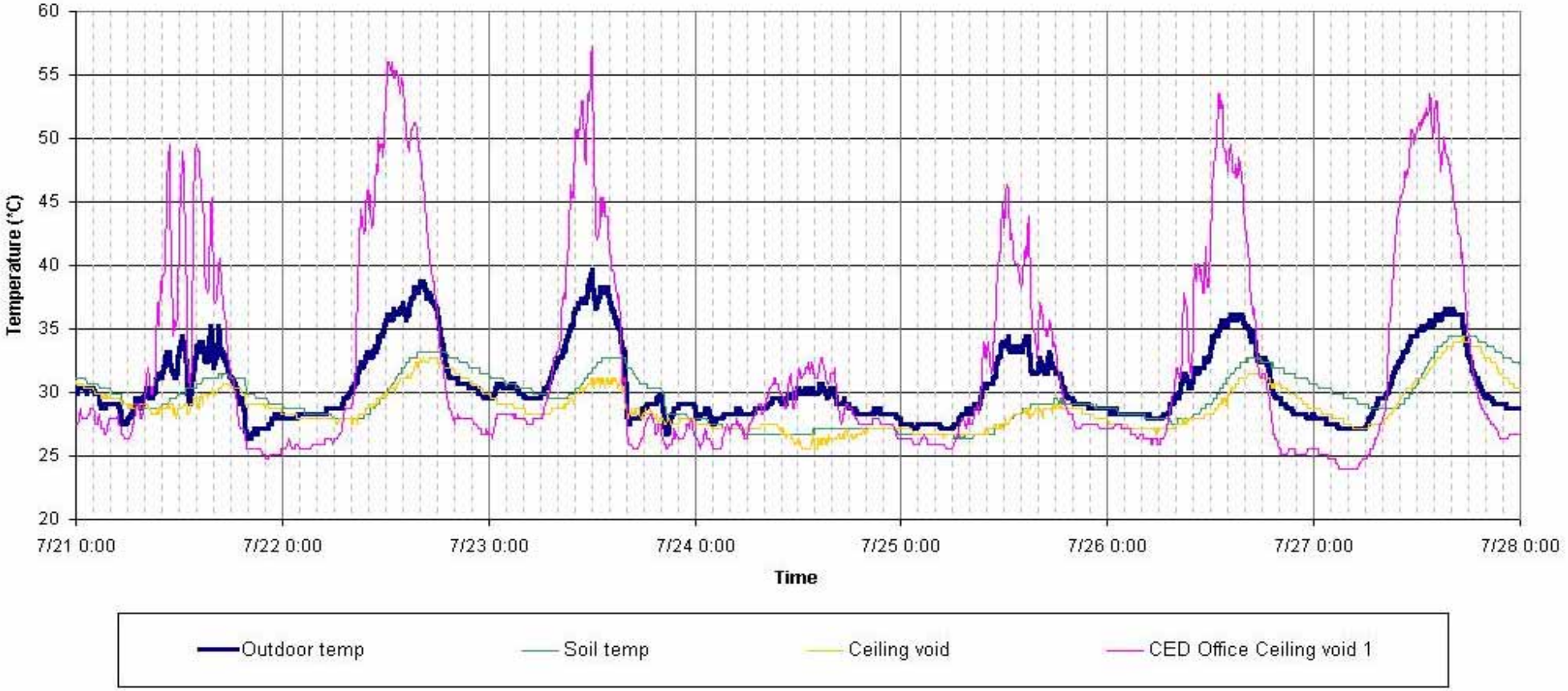
Green site office

Modular design

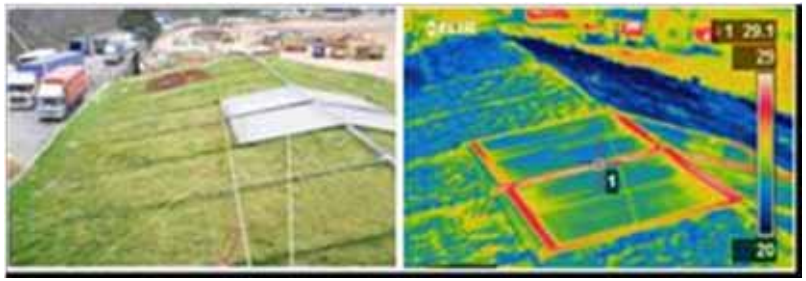
Green site office and typical site office

Water sprinkler

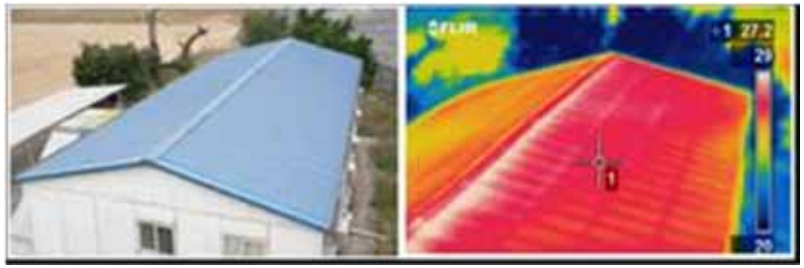
Green roof research at a construction site office in Hong Kong
在香港建筑地盘办事处的屋顶绿化研究



Infrared pictures:

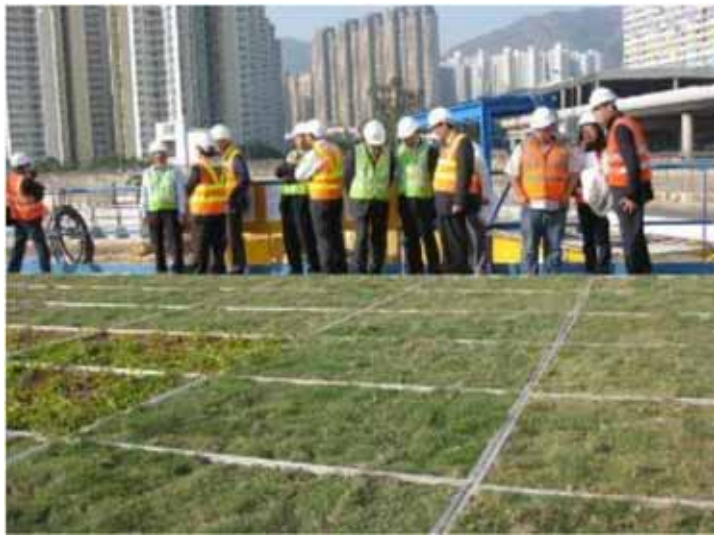


Green roof

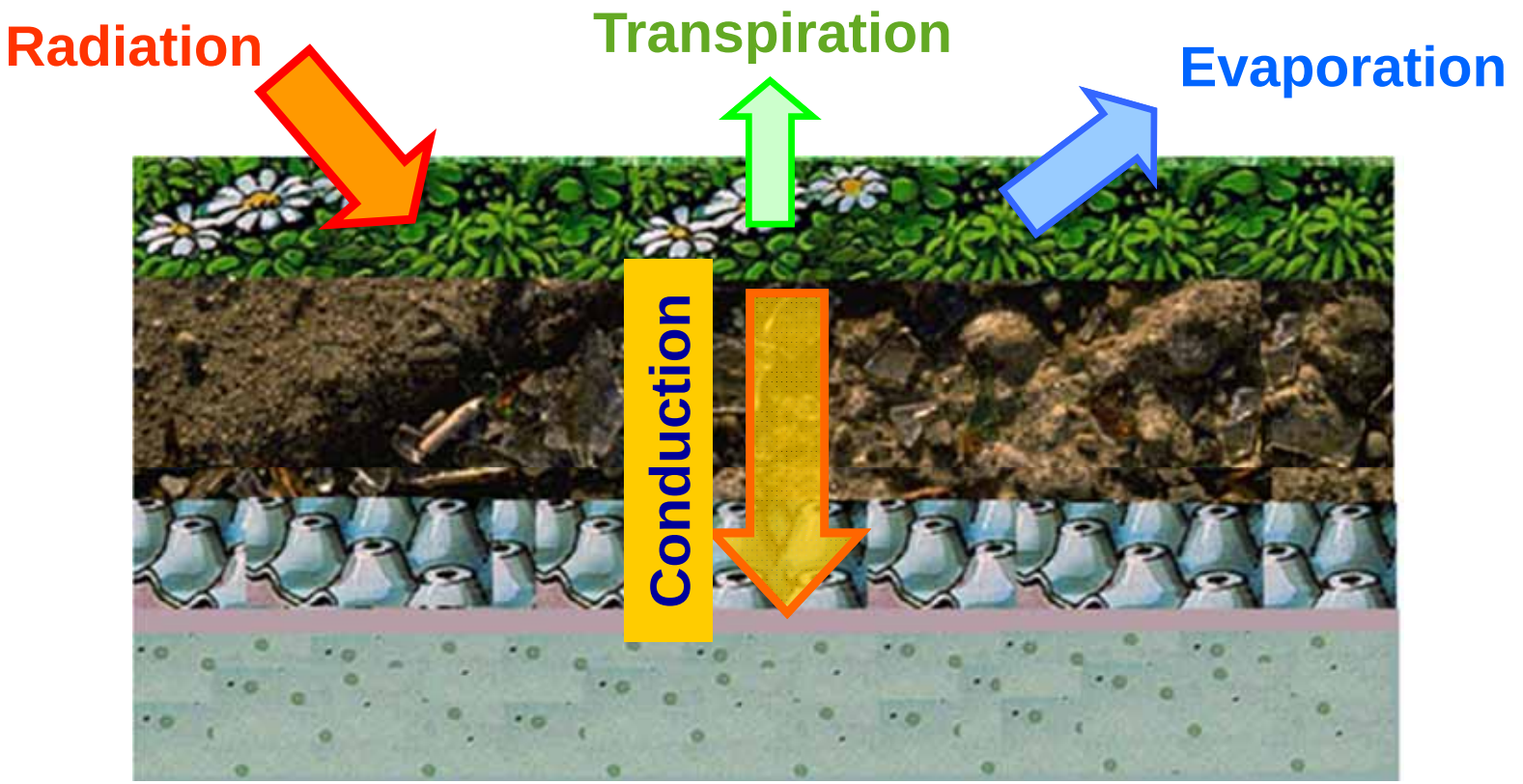


Conventional roof

Green roof and vertical green for construction site offices
在建筑地盘办事处的屋顶绿化和垂直绿化的应用



Thermal modelling of green roofs 绿化屋顶的导热建模



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

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

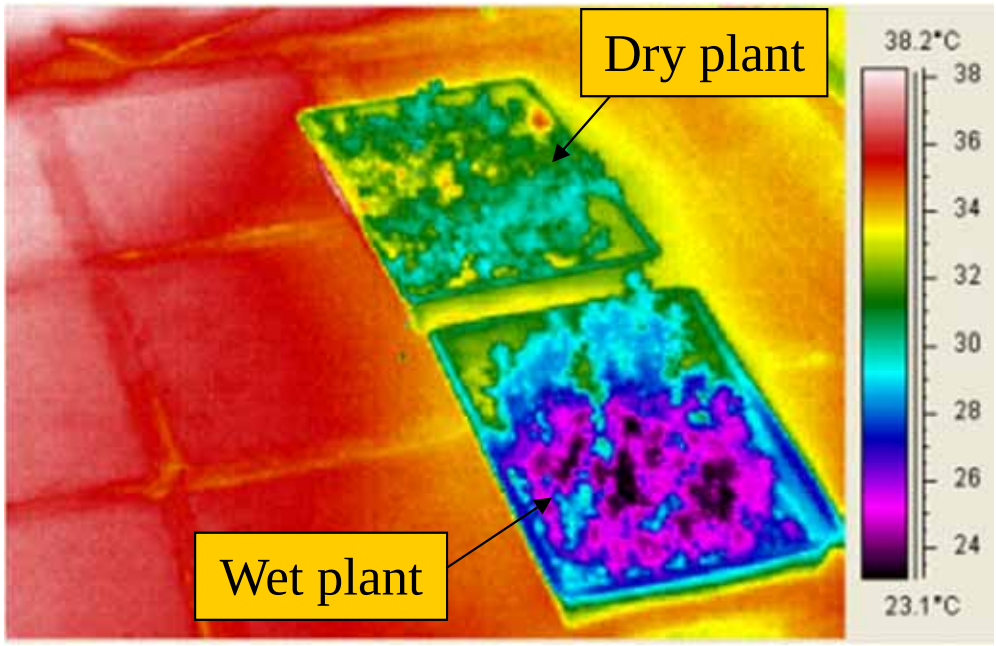
Conduction: $q'' = (T_{s1} - T_{s2}) / R_{total}$

Study of modular green roof systems (2007-2008)
模块化屋顶绿化系统的研究

Aluminum trays

Wooden boxes

Plastic trays

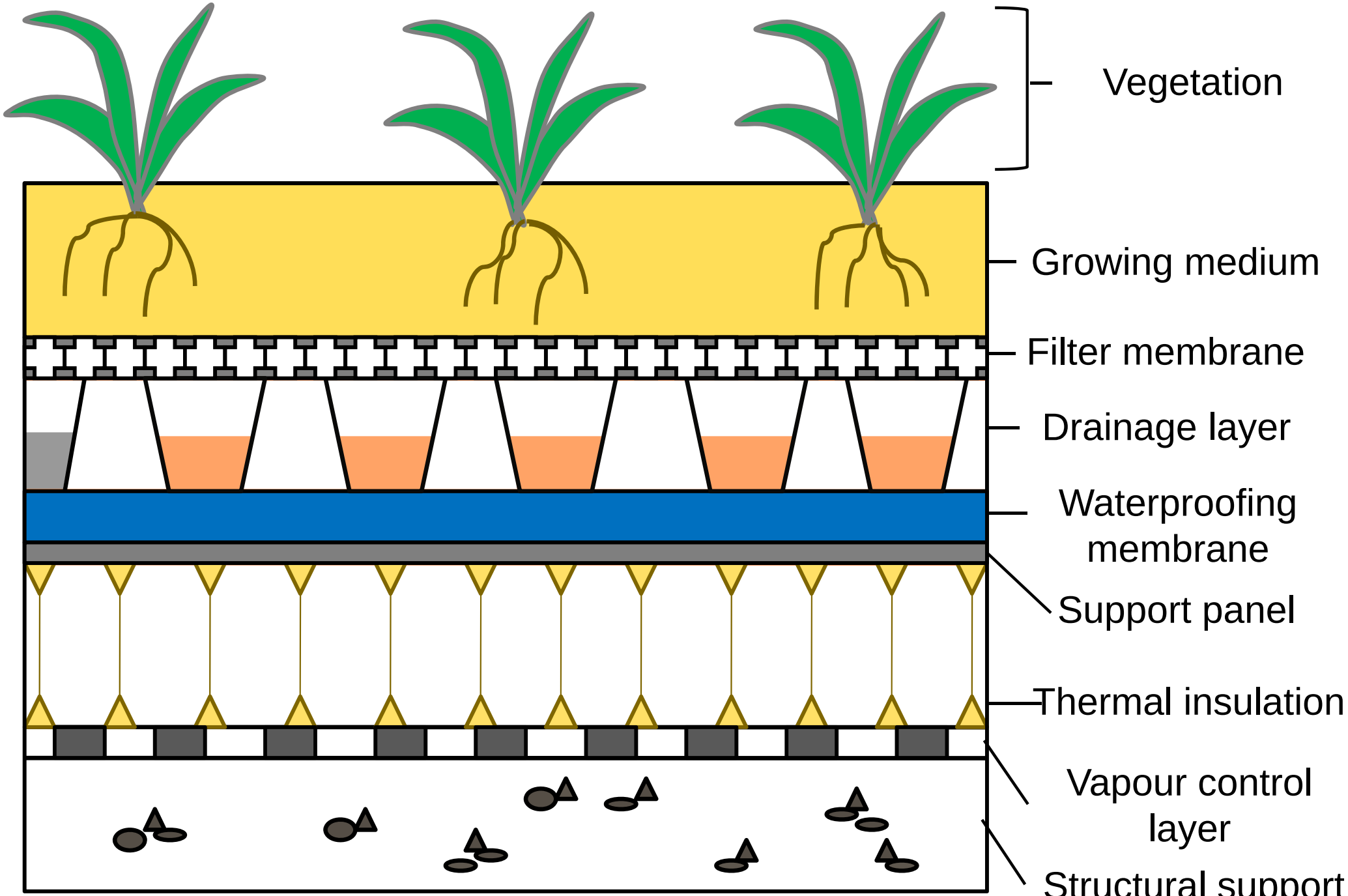


Plastic trays (infrared photo)

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

绿化屋顶系统: 德国（左）和日本（右）

Typical structure of extensive green roof
粗放型屋顶绿化的典型结构

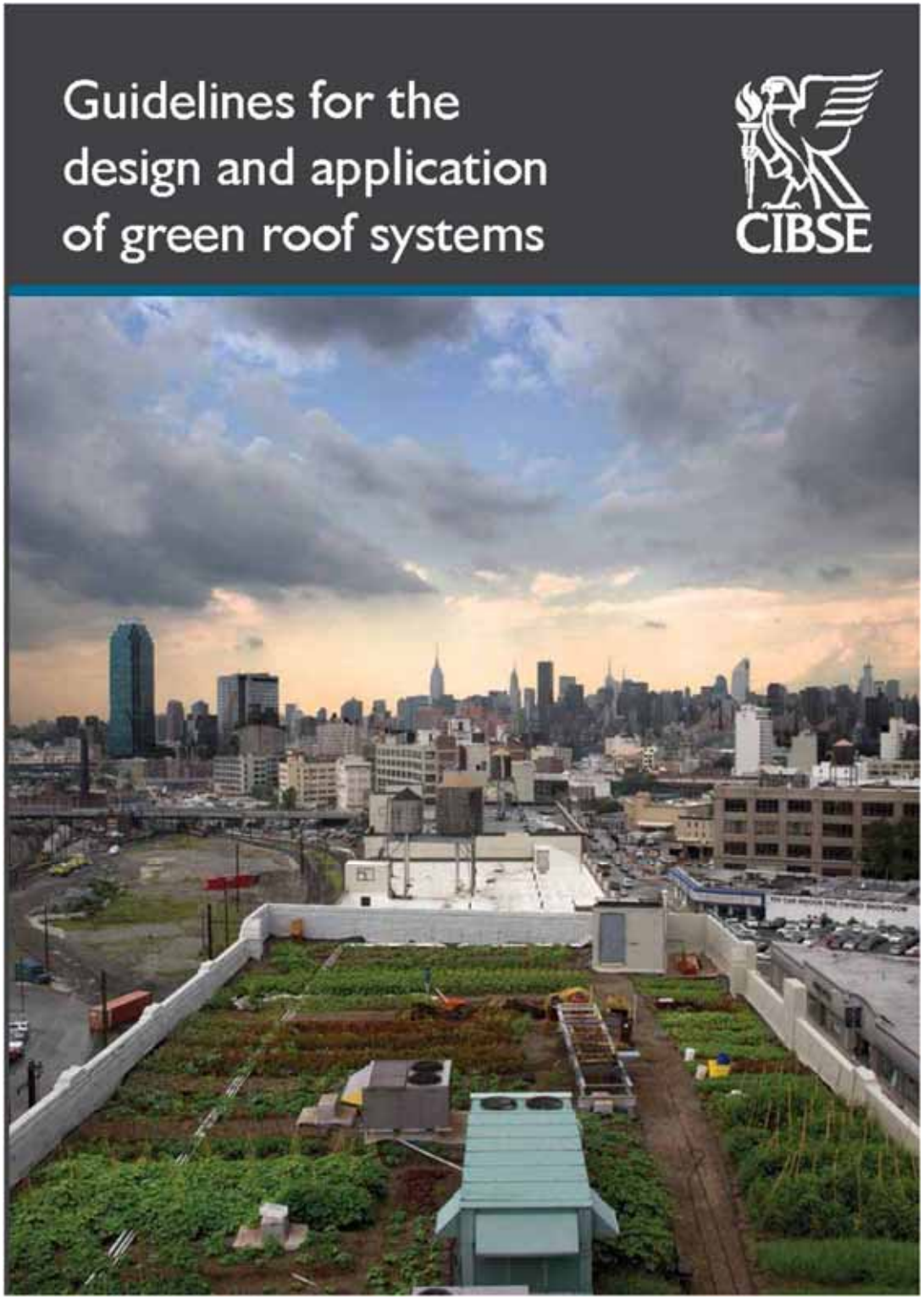


Green noise barrier 绿色隔音屏障

(Source: Highway Department, HK)

Introduction 引言

- Recent research studies 最近完成的研究:
  - Technical guidelines for green roof systems (done) 屋顶绿化系统的技术指南 (已经出版)
  - Integration of green roof and solar energy systems 绿化屋顶和太阳能系统的整合
  - Evaluate indoor living walls 室内活生墙的评估
  - Thermal regulation performance of living walls 活生墙的热调节性能
  - Year-round energy performance of vertical greening systems 垂直绿化系统的全年节能性能



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)
屋顶绿化系统的设计与应用指引

1. Introduction 引言
2. Scope 范围
3. Definitions 定义
4. Planning Requirements 规划要求
5. Design Considerations 设计注意事项
6. Construction Methods 施工方法
7. Maintenance Issues 维护问题
8. Project Management 项目管理

Integration of green roof and solar energy systems

绿化屋顶和太阳能系统的整合

(Photos taken by Dr Sam C M Hui)

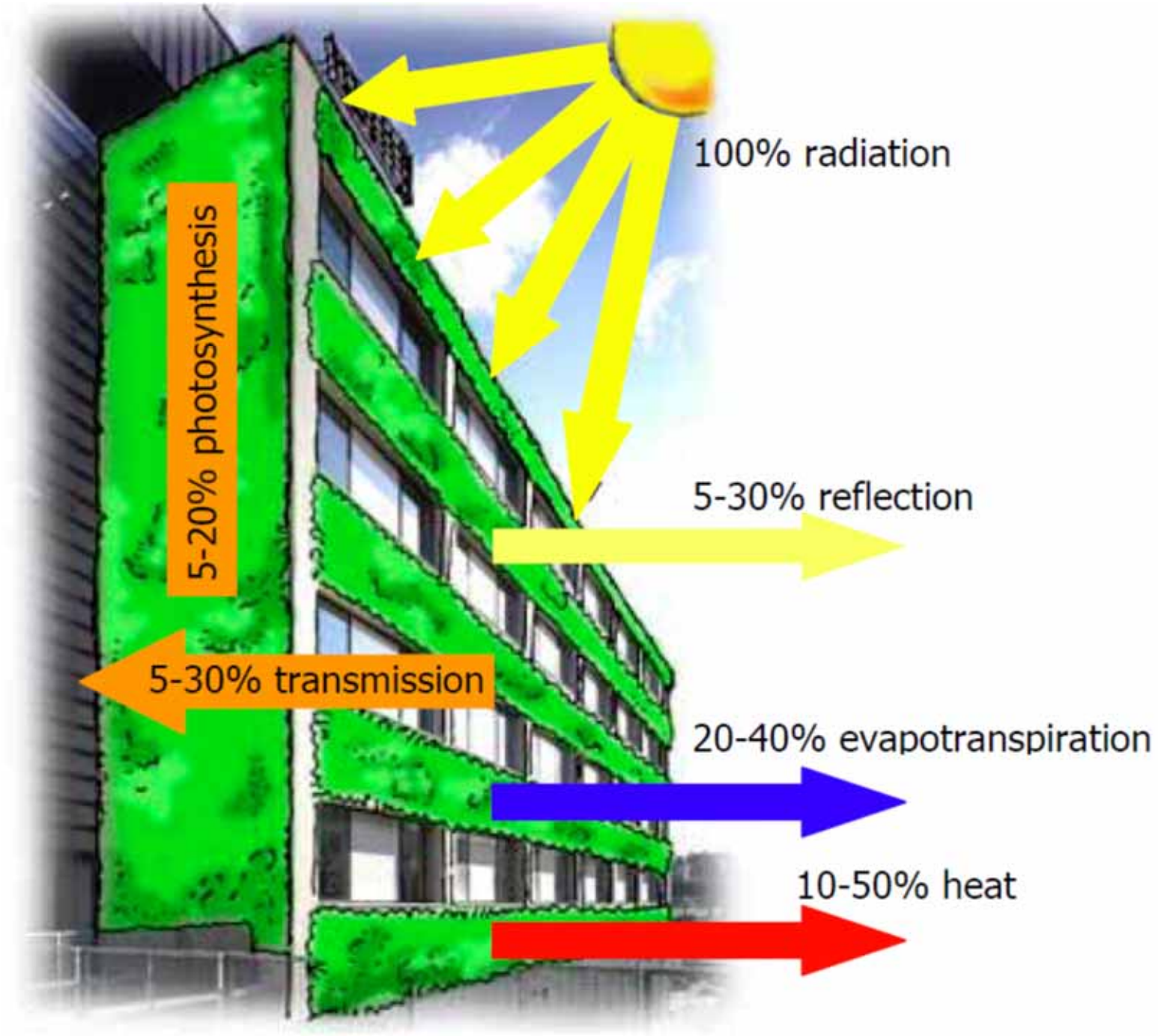
Indoor green wall 室内绿化墙

(International Commerce Centre 国际贸易中心)

(Photos taken by Dr Sam C M Hui)

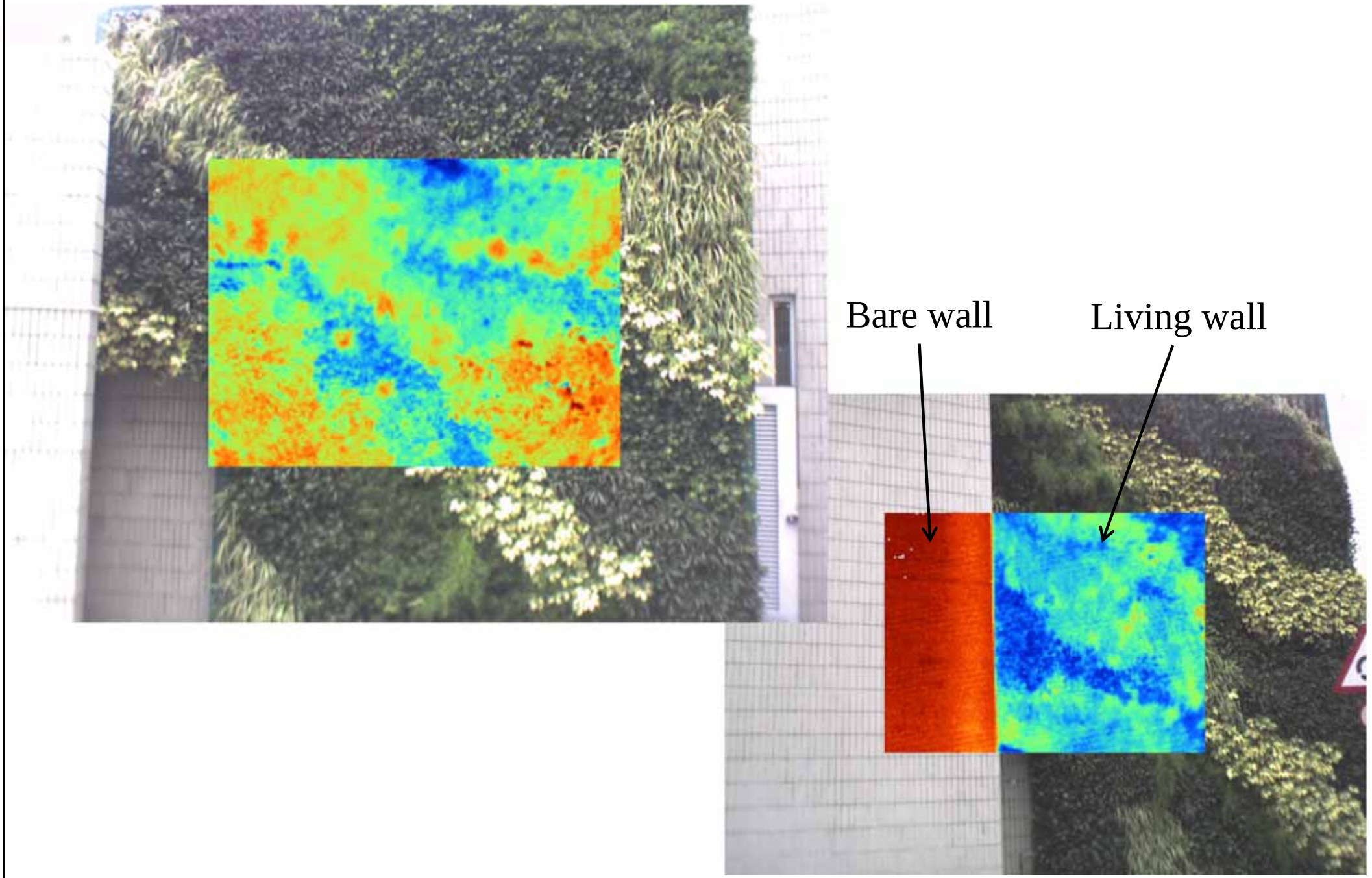
(International Finance Centre 国际金融中心)

Energy balance for a green wall 绿墙的能量平衡



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

Infra-red photos of vertical greening 垂直绿化的红外线照片



Introduction 引言

- Current studies 目前的研究:
  - Technical guidelines for vertical greening systems 垂直绿化系统的技术指南
  - Evapotranspiration analysis of vertical greening systems 垂直绿化系统的蒸散量分析
  - Double skin façade with vegetation plants 双层幕墙加植被植物
  - HK green roof and green building policy 香港的绿化屋顶与绿色建筑政策

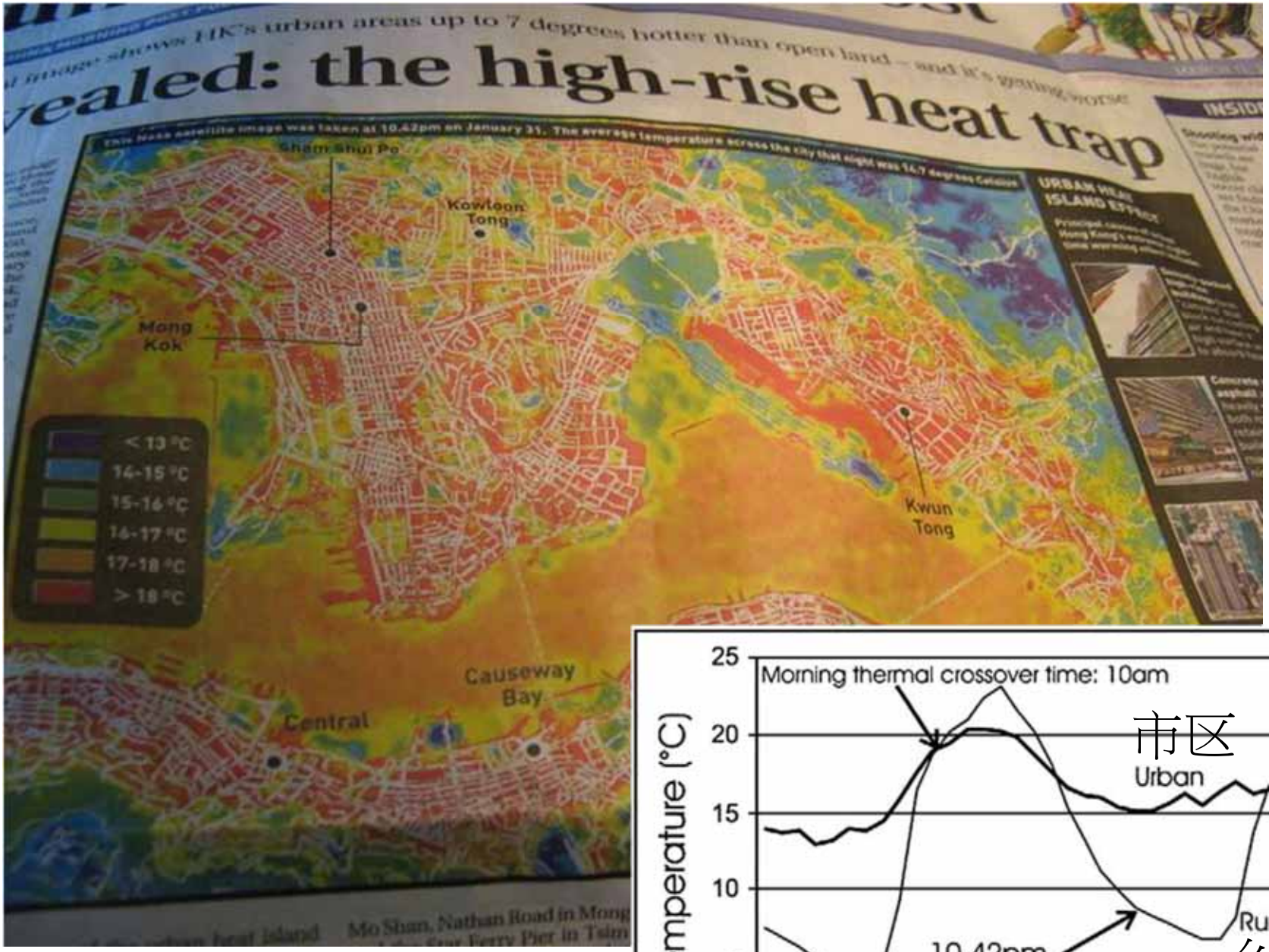
Potential benefits 潜在的好处

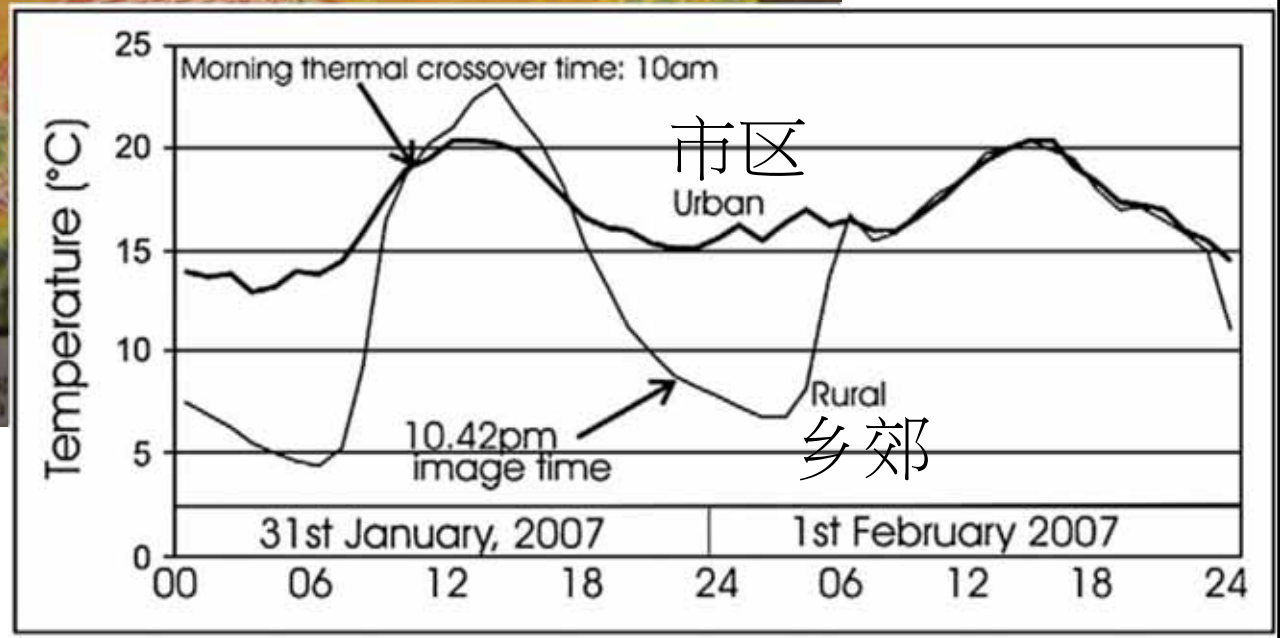
- Green roofs & vertical greening 绿化屋顶和垂直绿化
  - Building integrated vegetation 建筑综合性植被
  - Urban cityscape 城市景观
  - Green infrastructure 绿色基础建设
- Possible benefits: 可能的好处
  - 1. Environmental 环境的
  - 2. Economic 经济的
  - 3. Social 社会的

Potential benefits 潜在的好处

- 1. Environmental benefits: 环境的好处
  - - Mitigate urban heat island 缓解城市热岛
  - - Improve air quality 改善空气质量
  - - Stormwater management 改善城市雨水管理
  - - Create natural habitat 建立自然栖息地
  - - Increase biodiversity 增加生物多样性
  - - Insulate and absorb sound 隔音和吸音
  - - Possible urban farming 可作都市农业

Urban heat island in Hong Kong 香港城市热岛





(Source: SCMP and Hong Kong Observatory)

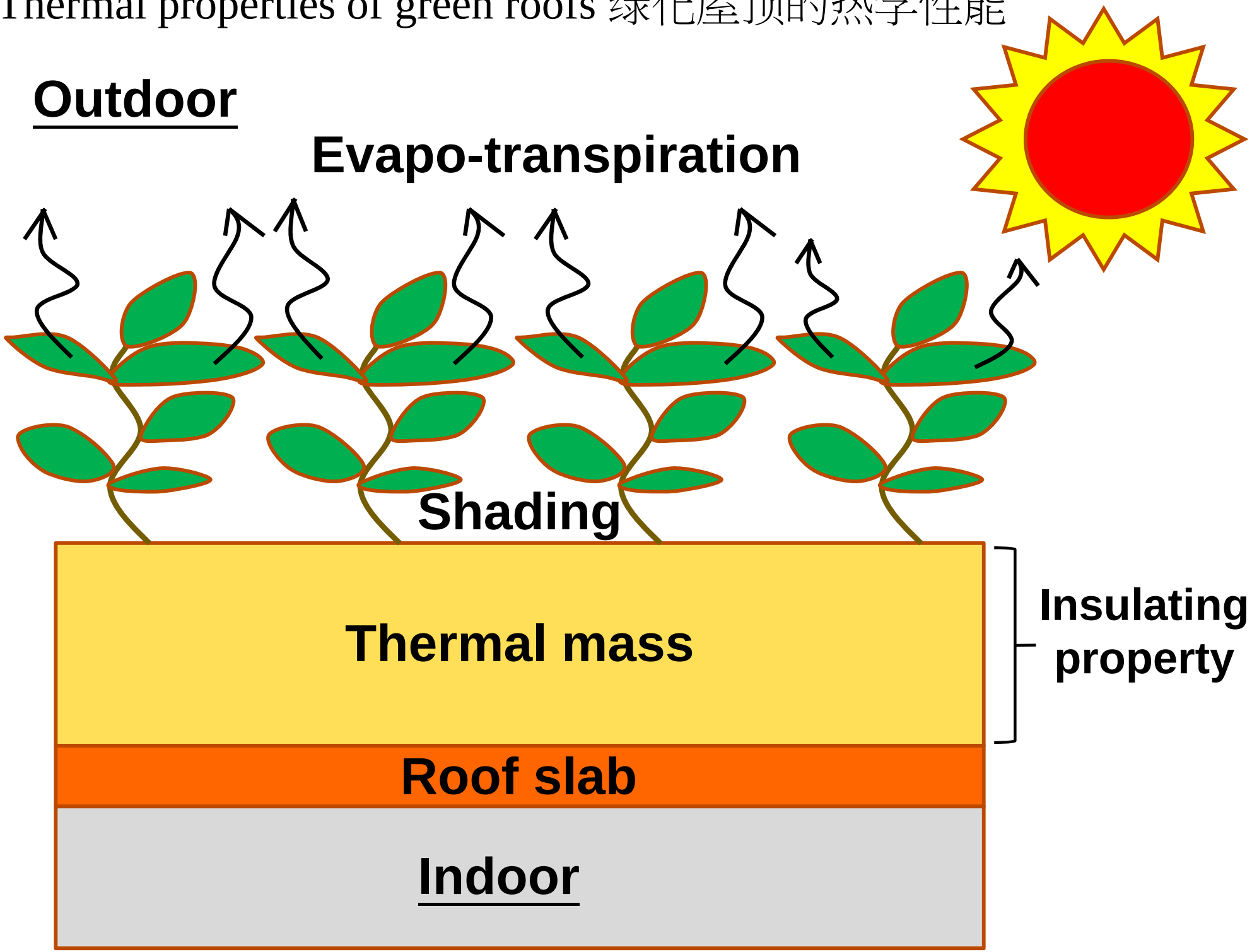
Rainstorm flooding problems in Hong Kong (2008)
在香港的暴雨水浸问题

(Source: www.accuweather.com)

Potential benefits 潜在的好处

- 2. Economic benefits: 经济的好处
  - - Improve roof durability 提高屋顶的耐久性
  - - Increase roof material lifetime 增加屋顶的寿命
  - - Reduce building cooling load and energy costs 降低建筑冷负荷和能源成本
  - - Provide open space & increase property value 提供开放空间，可增加物业价值
  - - Green building credit points & image 绿色建筑评估得分和形象

Thermal properties of green roofs 绿化屋顶的热学性能



Potential benefits 潜在的好处

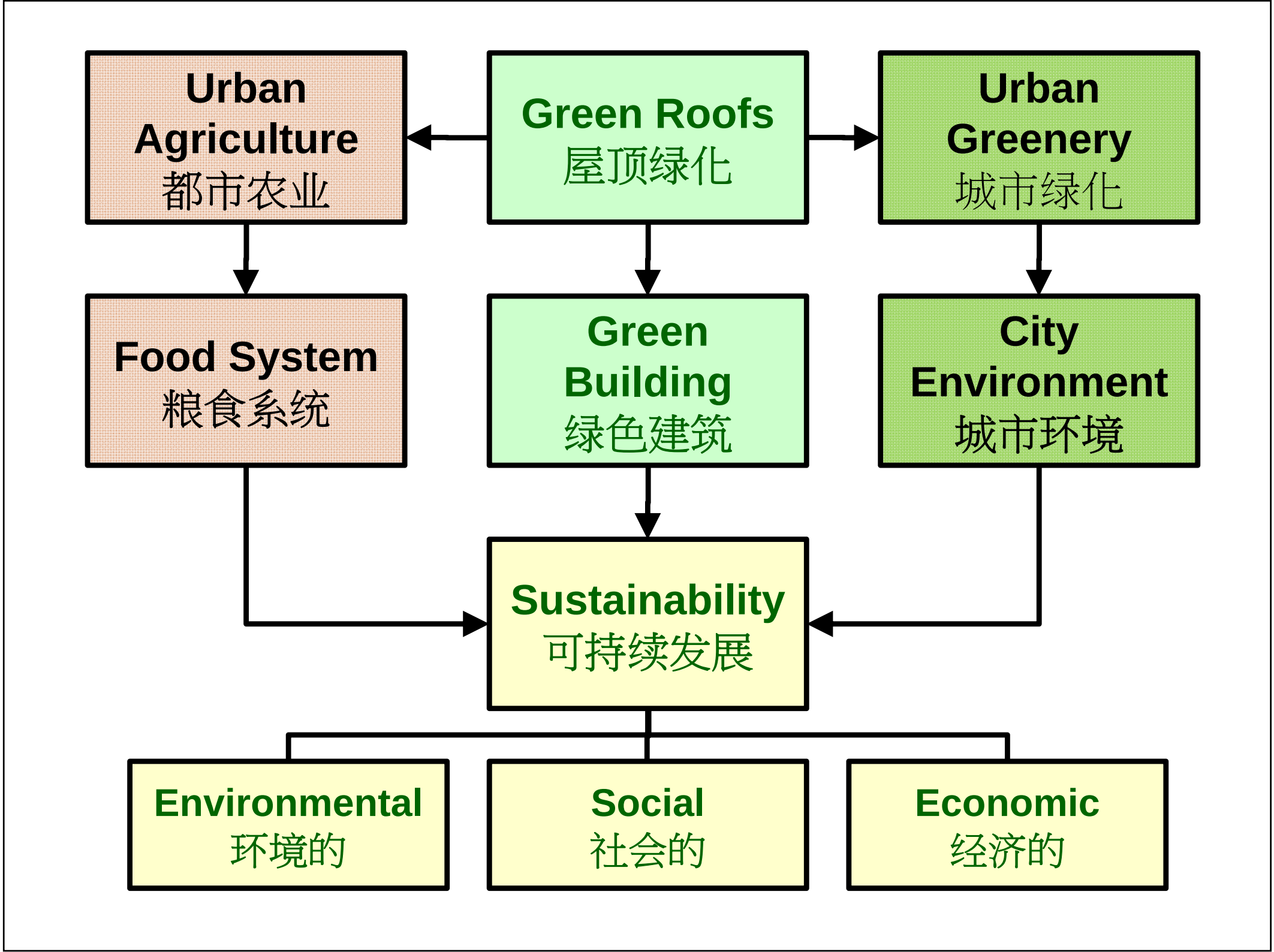
- 3. Social benefits: 社会的好处
  - - Aesthetic for city space 美化市容的空间
  - - Provide community green space & gardens for sports & leisure 提供社区绿地和花园，可作运动和的娱乐性
  - - Community participation 提供社区的积极参与
  - - Provide education opportunities 提供教育机会
  - - Enhance local employment 增加本地就业

School education green roof project 学校教育屋顶绿化工程

(Source: Ng Yuk Secondary School)

School education green roof project 学校教育屋顶绿化工程

(Source: Environment and Conservation Fund)


Urban Agriculture
都市农业
Green Roofs
屋顶绿化
Urban Greenery
城市绿化
Food System
粮食系统
Green Building
绿色建筑
City Environment
城市环境
Sustainability
可持续发展
Environmental
环境的
Social
社会的
Economic
经济的

Green roof examples
屋顶绿化的例子

- Green roof application is growing fast in Hong Kong in recent years 屋顶绿化的应用，近年来在香港正在快速增长
  - 1. Government projects (as demonstration)
    政府项目(如示范) (> 250 nos.)
  - 2. School projects (with incentives/subsidies)
    学校项目(奖励/补贴)
  - 3. Private projects (for “green” image)
    私人项目(为“绿色”的形象)

Examples of green roofs in Hong Kong 香港屋顶绿化的例子

Ocean Park 海洋公园

EMSD Headquarters 机电署总部

Parklane, TST 尖沙咀柏丽大道

HK Wetland Park 湿地公园

(Photos taken by Dr Sam C M Hui)

Hong Kong Wetland Park Phases II 香港湿地公园第二期

(Source: Architectural Services Department)

Greening at Tamar project 添马舰发展工程的绿化

(Photos taken by Dr Sam C M Hui)

New prison: green roof 新监狱的屋顶绿化

(Source: ArchSD)

Government green roof projects 政府绿化屋顶项目

Sewage treatment plant 污水处理厂

Refuge room 垃圾房

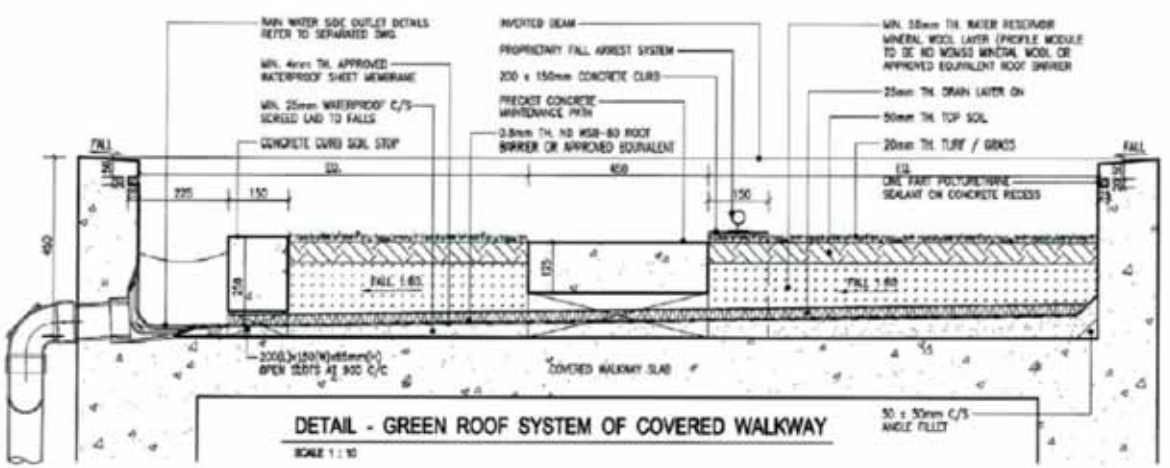
Sewage pumping station
污水泵站

(Source: Drainage Services Department and Housing Authority)

Roof greening on covered walkway 有盖行人道屋顶绿化

(Source: Housing Department, HK)

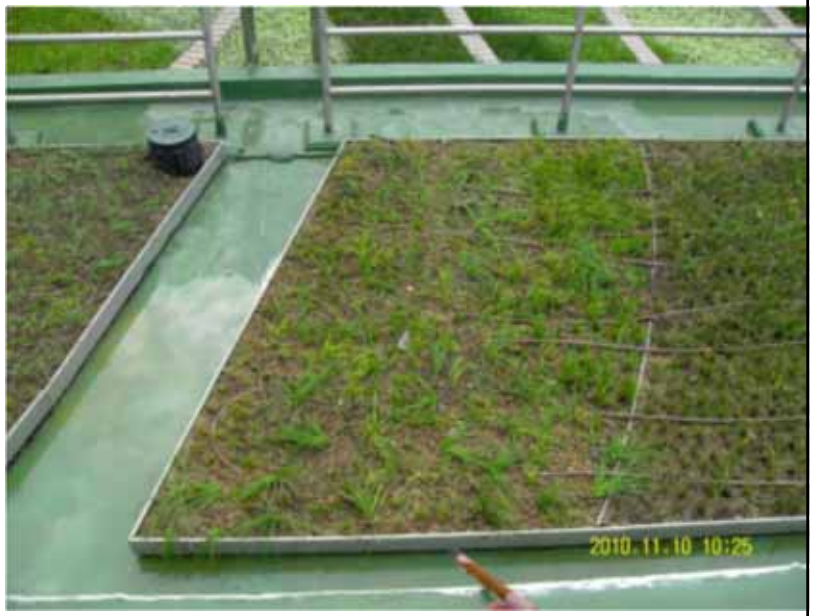
(Photo taken by Dr Sam C M Hui)



School green roof project 学校屋顶绿化工程

(Source: Architectural Services Department)

School green roof project 学校屋顶绿化工程



(Source: Architectural Services Department)

HKU Centennial Campus 香港大学百周年校园

(Photos taken by Dr Sam C M Hui)

Introduce greening on existing rooftops 现有的屋顶引入绿化

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)
屋顶绿化农耕(铜锣湾希慎广场)

(Photos taken by Dr Sam C M Hui)

Vertical greening examples
垂直绿化的例子

- Common reasons for vertical greening 采用垂直绿化的常见原因 :
  - Aesthetic (how it looks) 美学(怎么样)
  - Cognitive (meaning) 认知(意义)
  - Experiential (use) 体验(使用)
  - Planning and financial gains ($) 规划和财务收益
  - Pollution absorption (air) 吸收污染(空气)
  - Ecology (habitats) 生态(栖息地)

Vertical greening examples
垂直绿化的例子

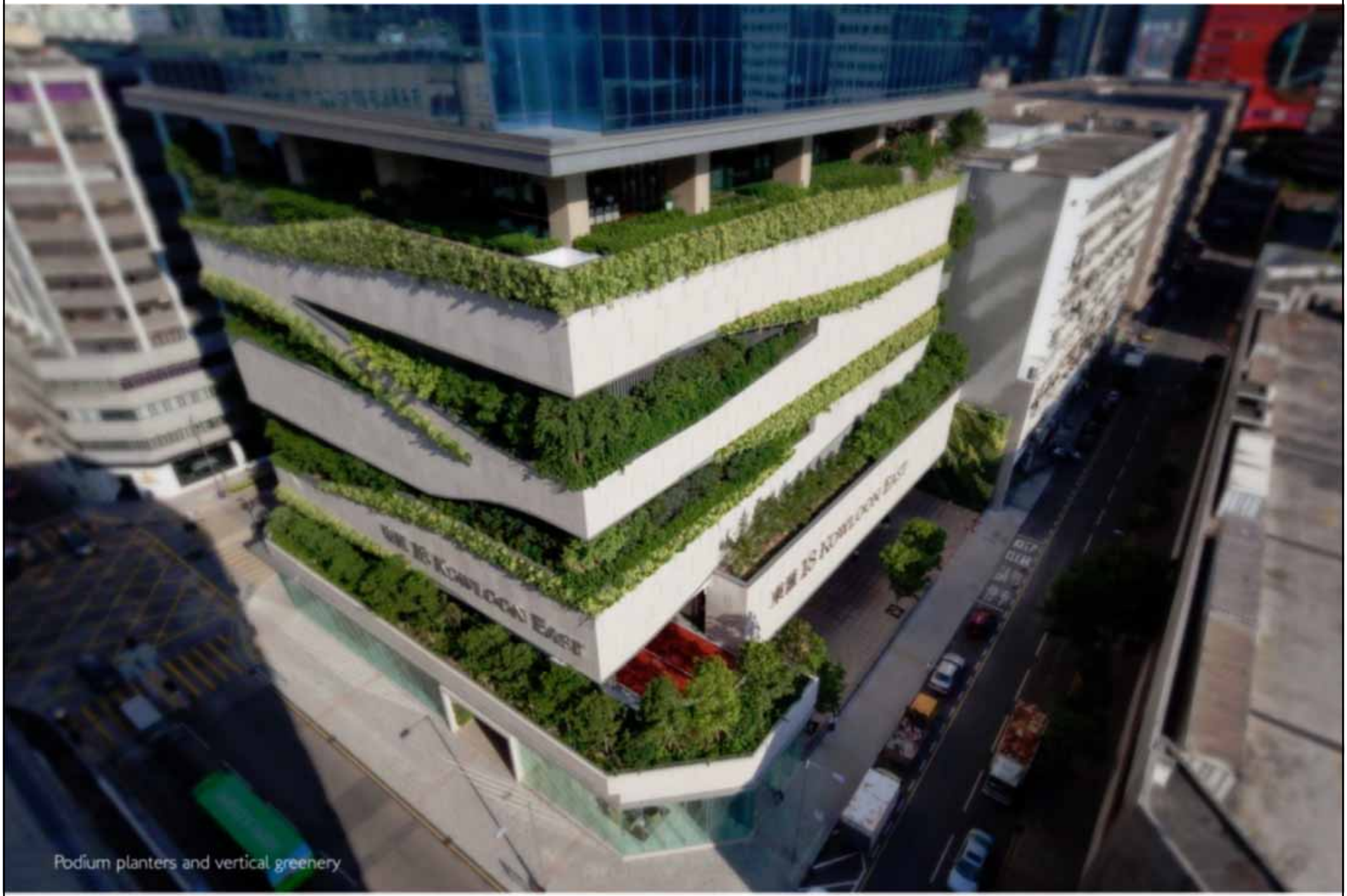
- Application methods of vertical greening 垂直绿化的应用方法：
  - 1. Building façades or outdoor vertical surfaces 建筑外墙或户外垂直表面
  - 2. Interior walls or indoor vertical surfaces 室内墙壁或室内垂直表面
  - 3. Noise barriers (e.g. along the roads)隔音屏障(例如在道路两旁)
  - 4. Slopes 斜坡

An example of vertical greening 垂直绿化的一个例子

(Source: CityWalk, Tsuen Wan, 荃湾荃新天地, www.citywalk.com.hk)

A green wall in Central 中环的绿墙

A green wall project in Kowloon Bay 在九龙湾一个绿化墙工程



(18 Kowloon East)

A green wall project in Wanchai 在湾仔一个绿化墙工程

(The Hennessy)

Green wall for exhibition function 展览活动的绿墙

(Source: www.greening.gov.hk)

Government demonstration projects 政府示范项目

For a housing estate

For a school building

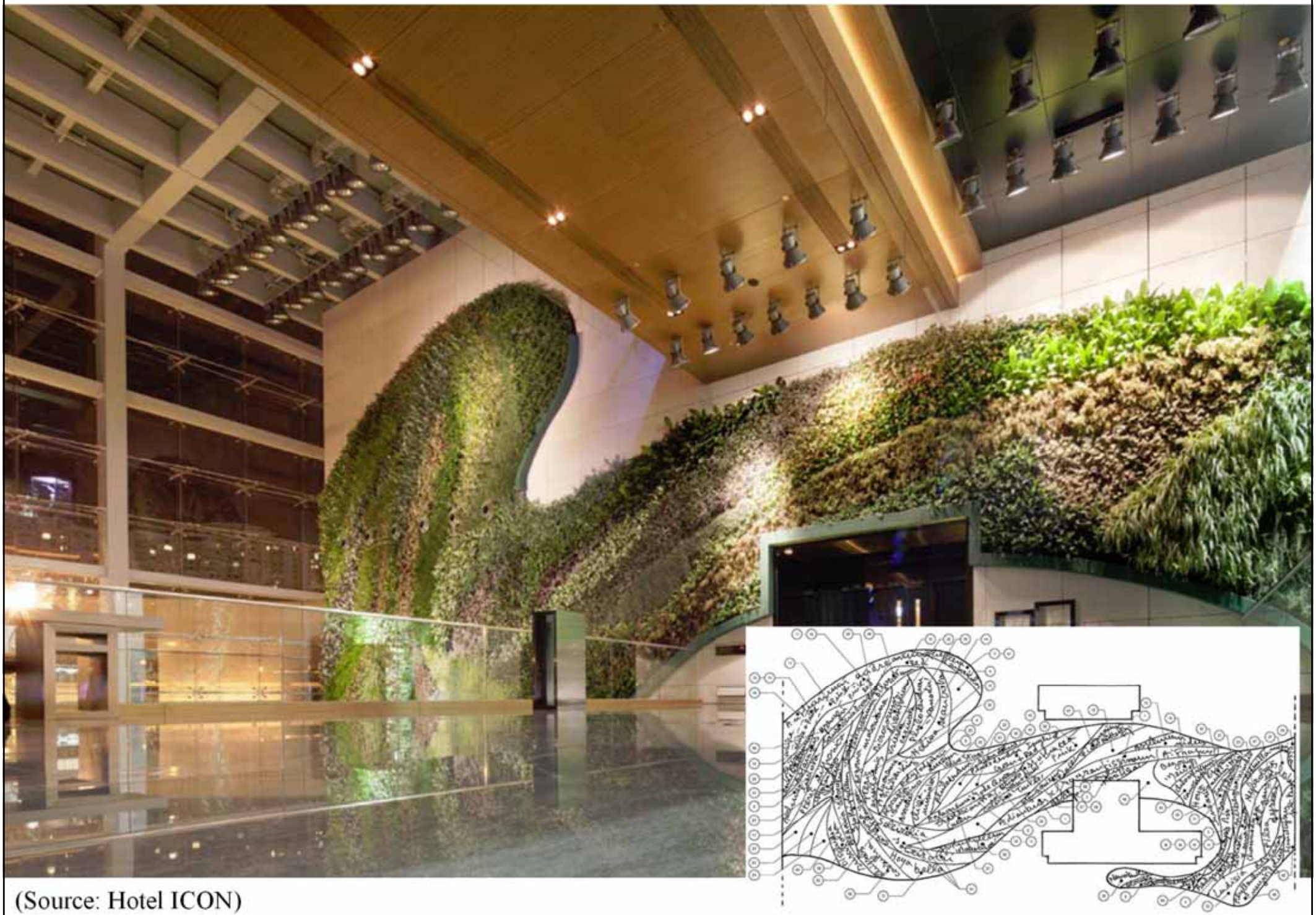
For a government building (EMSD Headquarters)

(Source: www.greening.gov.hk)

A school green wall project 一所学校绿化墙项目

(Source: www.everplant.com.hk)

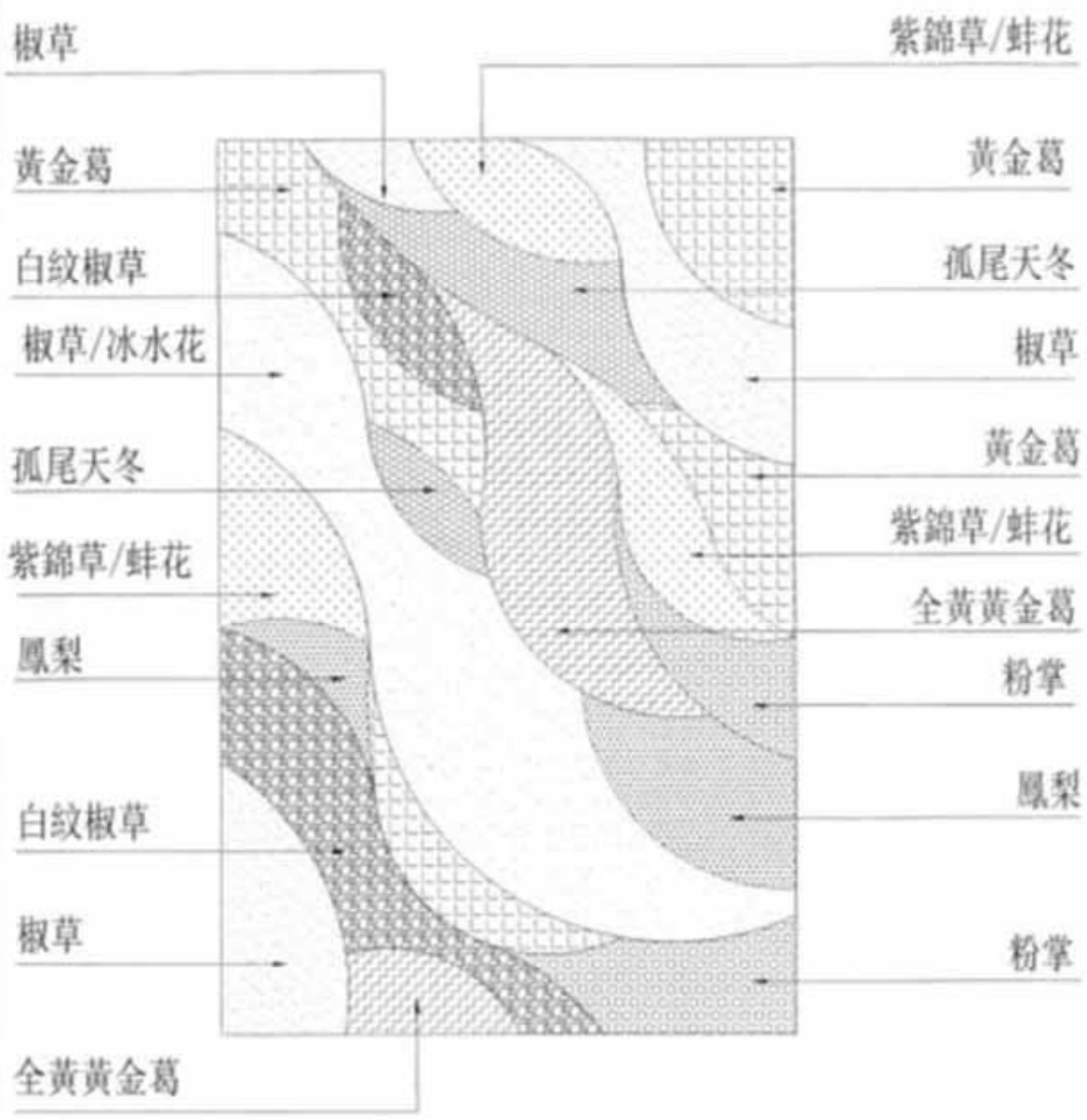
An indoor green wall in a hotel 在酒店的一个室内绿化墙



(Source: Hotel ICON)

Indoor green wall 室内绿化墙

Indoor green wall 室内绿化墙



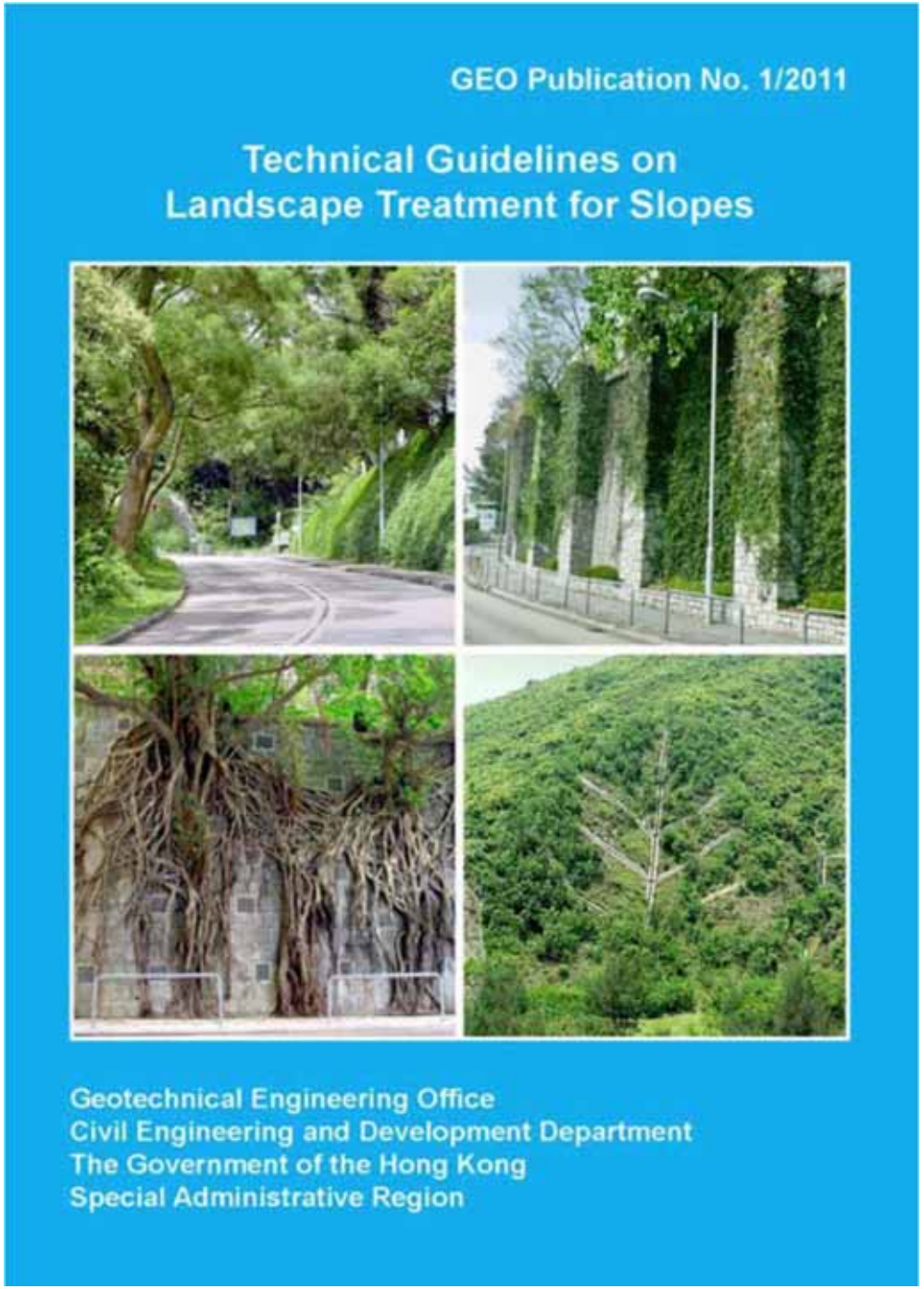
1 ELEVATION
Scale: 1:50

(City Walk 2, Tsuen Wan, 荃湾荃新天地2期)

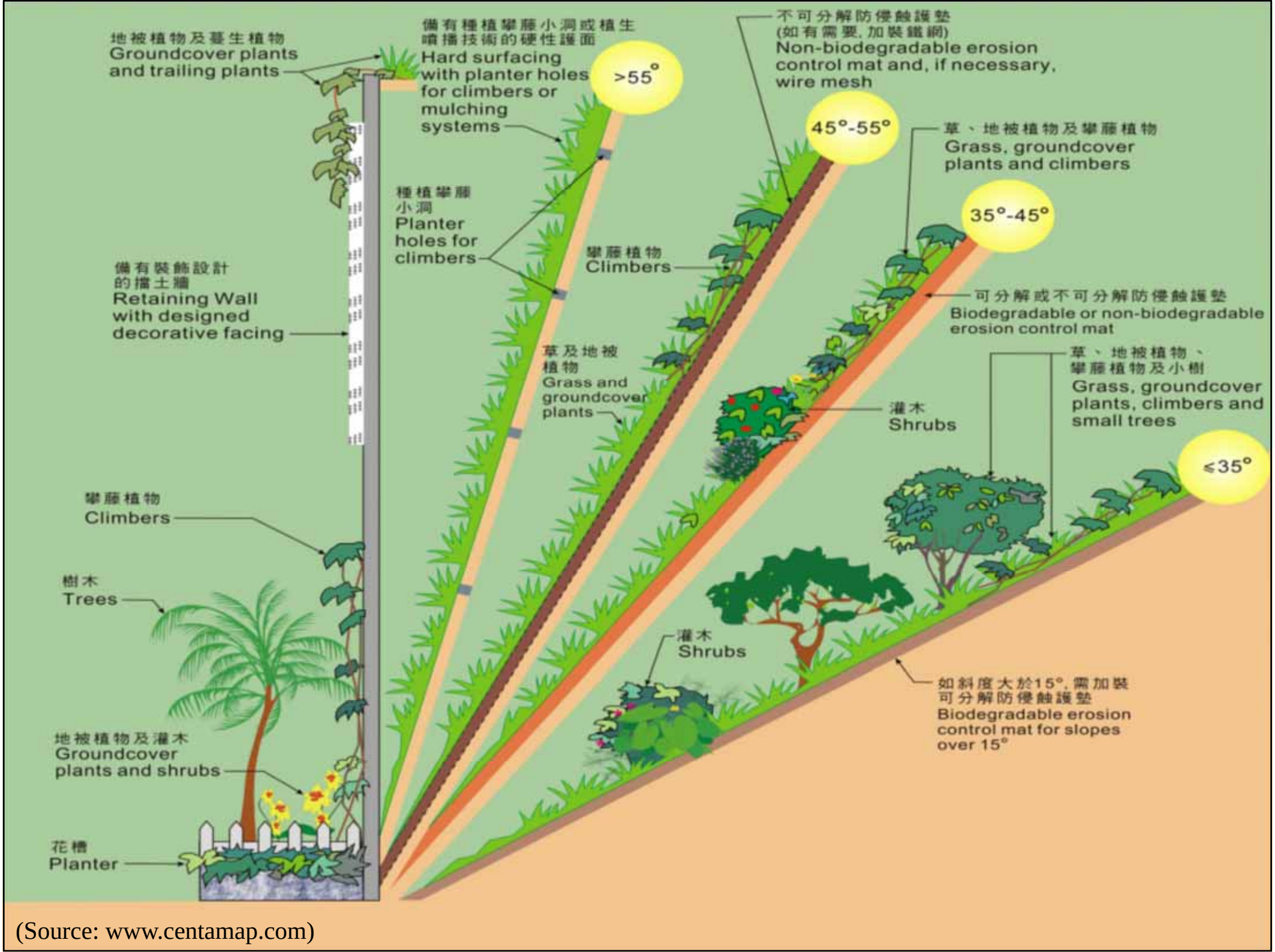
Greening on highway structures 绿化公路结构

(Source: Highway Department, HK)

Greening on slopes 斜坡上绿化

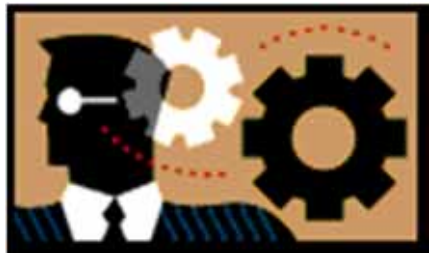


(Source: Civil Engineering and Development Department)



(Source: www.centamap.com)

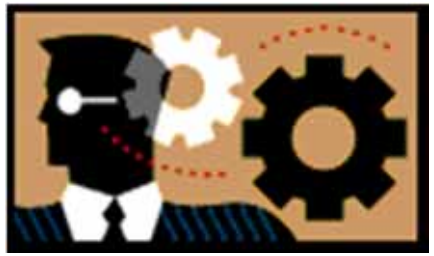
Major considerations
主要考虑因素



- Key factors for planning 主要规划因素
  - Structural loading 结构负荷
  - Accessibility 能否容易到达
  - Waterproofing 屋面防漏水
  - Drainage 排水渠务
  - Maintenance 维护保养

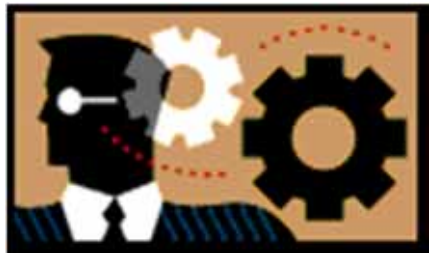
- Other design considerations 其他设计考虑
  - Selection of plants (e.g. hardy plants) 选择植物
  - Stakeholders' involvement & support 参与支持

Major considerations
主要考虑因素



- Climatic factors 气候因素
  - Typhoons: strong wind might blow away the vegetation and soil 台风：强风会吹走植被土壤
  - Heavy rainfalls: hold and drain the rain water without creating pools of stagnant standing water 大雨：不积水池的雨水排水
  - High temperature: affect some plant species 高温：某些植物物种的影响
  - Strong sunlight: solar and UV radiation 强烈的阳光：太阳能和紫外线辐射

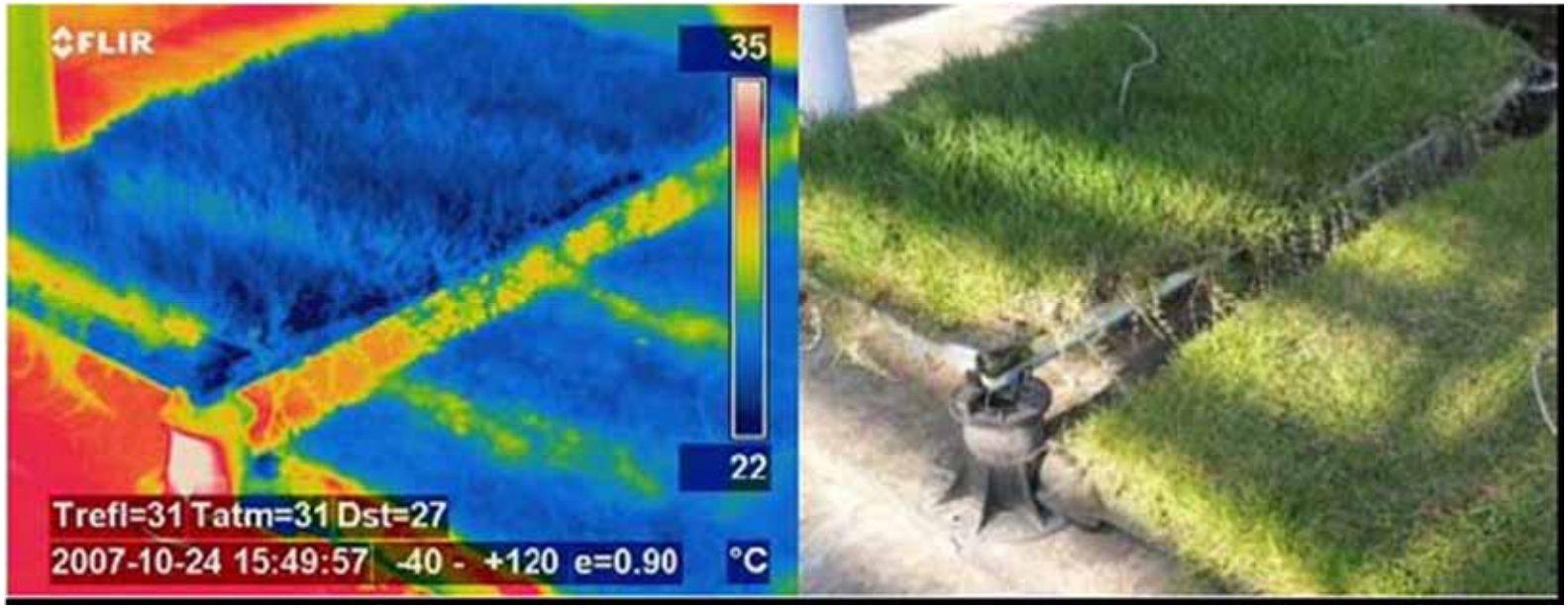
Major considerations
主要考虑因素



- High-rise buildings: very limited roof spaces
  高层建筑：屋顶的空间非常有限
  - Better to apply green roofs to medium- or low-rise buildings/structures or podium roofs 更好地适用于中或低矮建筑物/构筑物或平台屋顶绿化
    - Podium/sky gardens 平台，空中花园
- Structural loading 结构荷载
  - Determine validity and cost 确定有效性和成本
  - For existing buildings 对于现有建筑物
    - Light-weight greening systems 轻质绿化系统

Green roof on a low-rise building 在低层建筑的屋顶绿化

(Source: Hongkong Electric Co., Ltd.)



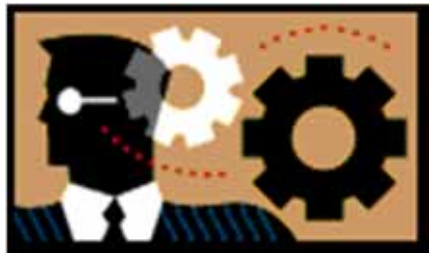
Infrared photo for assessing thermal effects

评估热效应的红外照片

Typical hardy plants (sedums) used for green roofs

用于绿化屋顶的典型耐寒的景天植物

Major considerations
主要考虑因素

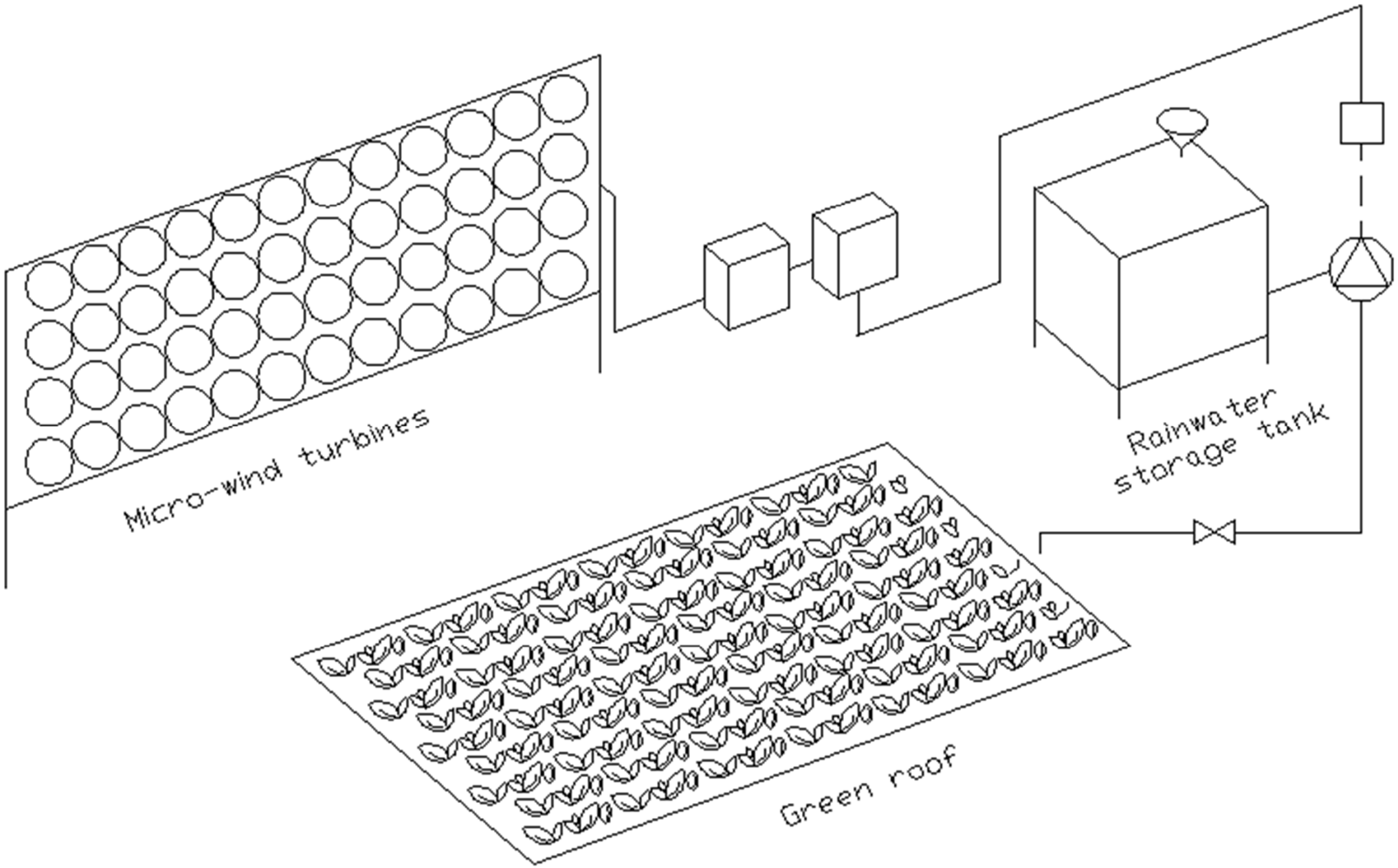


- Costs and commitments 成本和承诺
  - Capital cost (direct & indirect costs) 资本成本(直接和间接成本)
  - Recurrent maintenance costs 经常维修保养费用
  - Life-cycle costs 生命周期成本
  - Risk of failure costs 失败成本的风险
  - Maintenance commitments 维护承诺
  - Ownership 拥有权

Development trends
发展趋势

- Sustainable technologies 可持续发展技术
  - Rainwater harvesting 雨水收集
  - Renewable energy (e.g. solar photovoltaic & wind) 可再生能源(如太阳能光伏和风能)
  - Composting (for producing fertilizer) 堆肥(用于生产肥料)
- Farming & food production 农业和食品生产
  - Agricultural green roofs 农业屋顶绿化
  - Edible living walls 可食用的活生墙

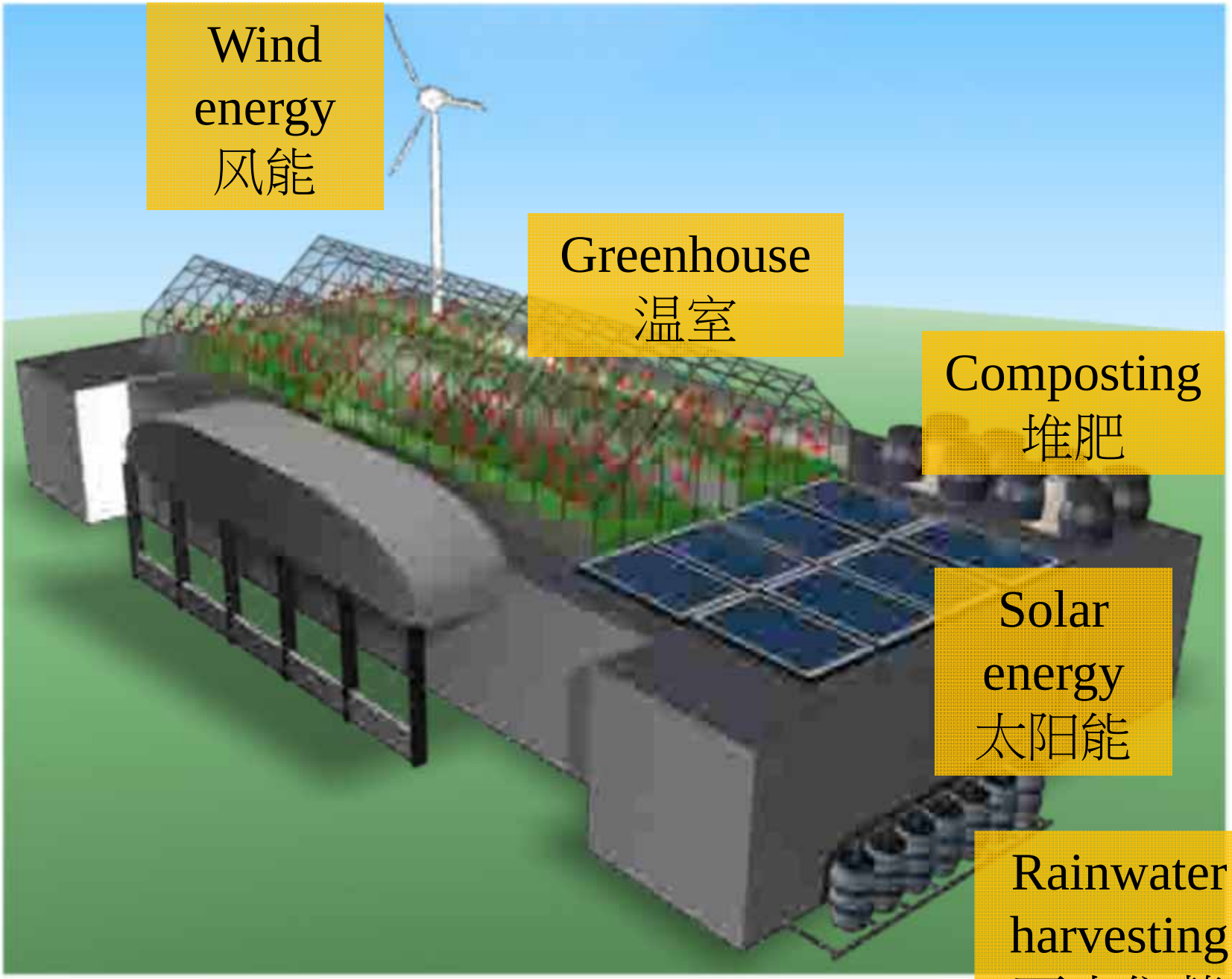
Integration of green roof, rainwater recycling and renewable energy
屋顶绿化、雨水回收利用和可再生能源的集成



Integration of green roof and solar energy systems 绿化屋顶和太阳能系

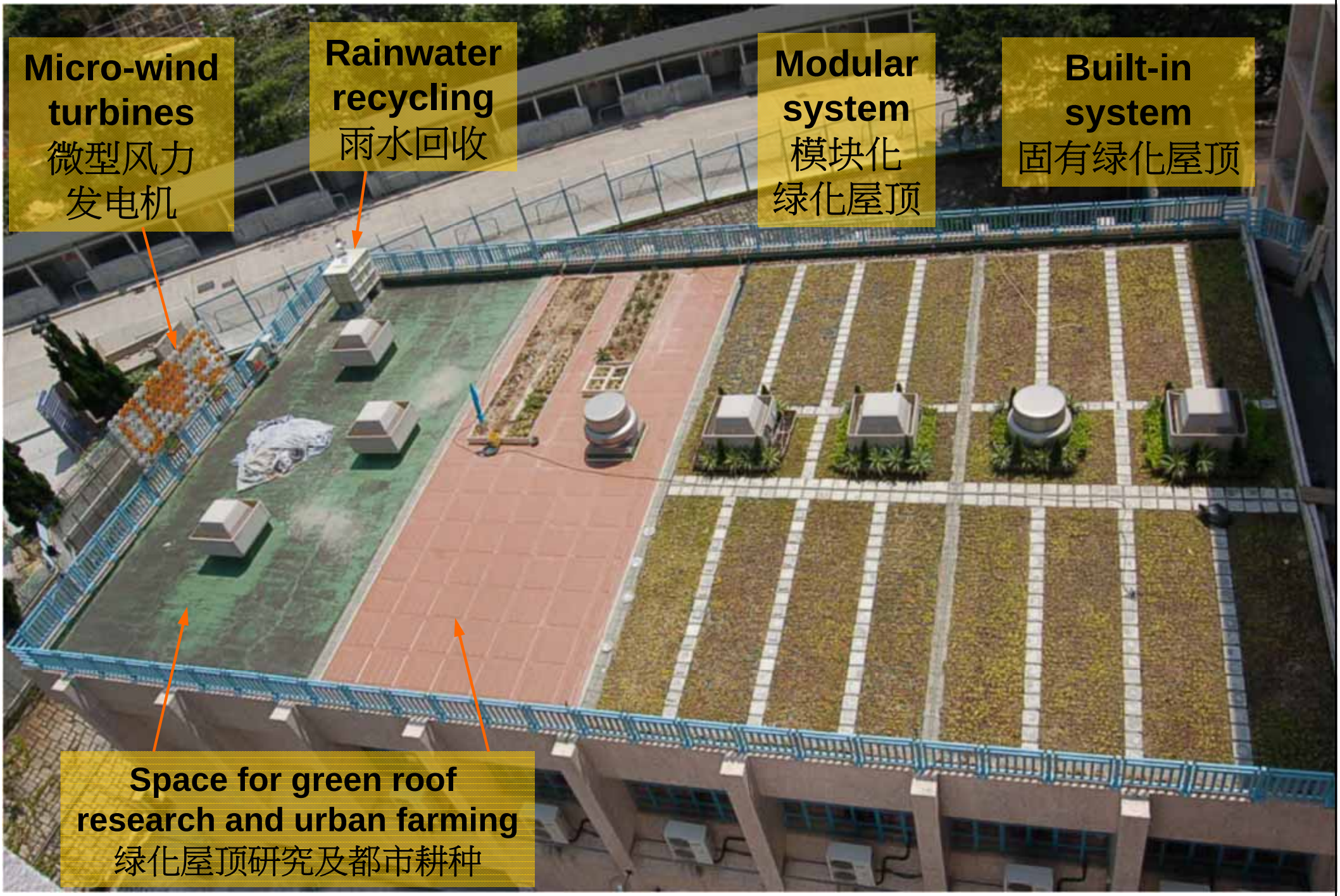
(Source: www.zinco.de)

Sustainable rooftop farming 可持续屋顶耕种



(Source: www.skyvegetables.com)

Green roof research with integrated systems 绿色屋顶的综合系统研究



Urban farming on green roofs 绿化屋顶都市农耕

Farming on the roof
农业上的屋顶

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 食用垂直花园

(Source: www.lifeisagarden.com.au)

Soil-less green roof farming (purple potato) 无土屋顶绿化种植紫薯

[An elderly home in HK 香港的一间安老院]

(Photos taken by Dr Sam C M Hui)

Conclusions 结论

- Green roofs and vertical greening are developing fast in Hong Kong 屋顶绿化和垂直绿化在香港正快速发展
- New techniques are applied to urban greening 新技术应用到城市绿化
- More research is needed to determine suitable technologies and policy for promoting them 需要更多的研究，以确定合适的技术和政策，以促进城市绿化

THANK YOU 谢谢 !!

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