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# Research on Green Roofs and Vertical Greening in Hong Kong

## 香港绿化屋顶和垂直绿化的研究



1911-2011

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- Introduction 引言
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- 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<sup>2</sup>

- Population 人口: 7.06 millions

- Population density 人口密度: 6,480 persons/ km<sup>2</sup>



- 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)



Another type of green roof in Hong Kong 香港的另类绿色屋顶



Eastbtm



# Introduction 引言

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



# 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

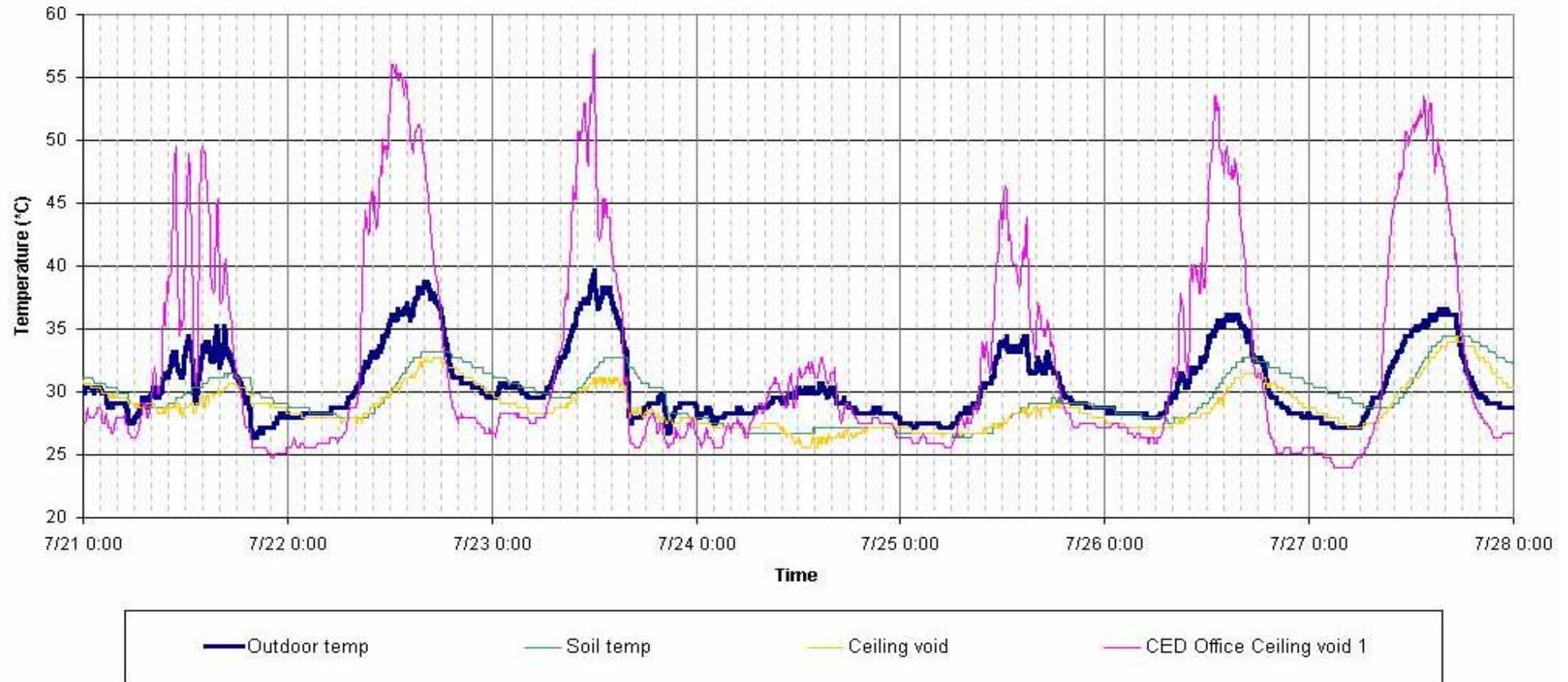


Green site office and typical site office

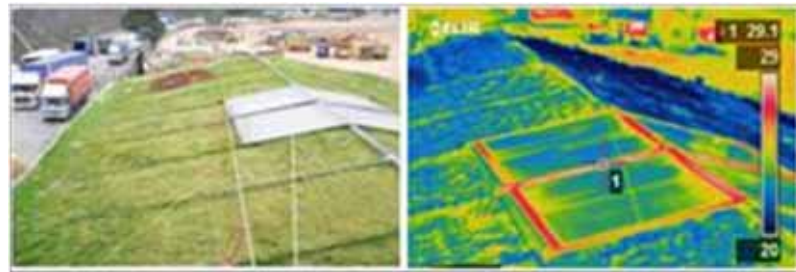


Water sprinkler

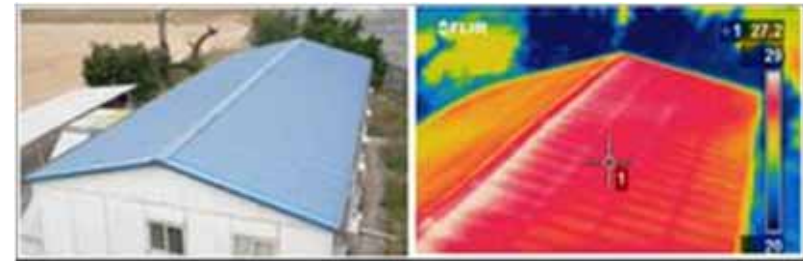
# Green roof research at a construction site office in Hong Kong 在香港建筑地盘办事处的屋顶绿化研究



## Infrared pictures:

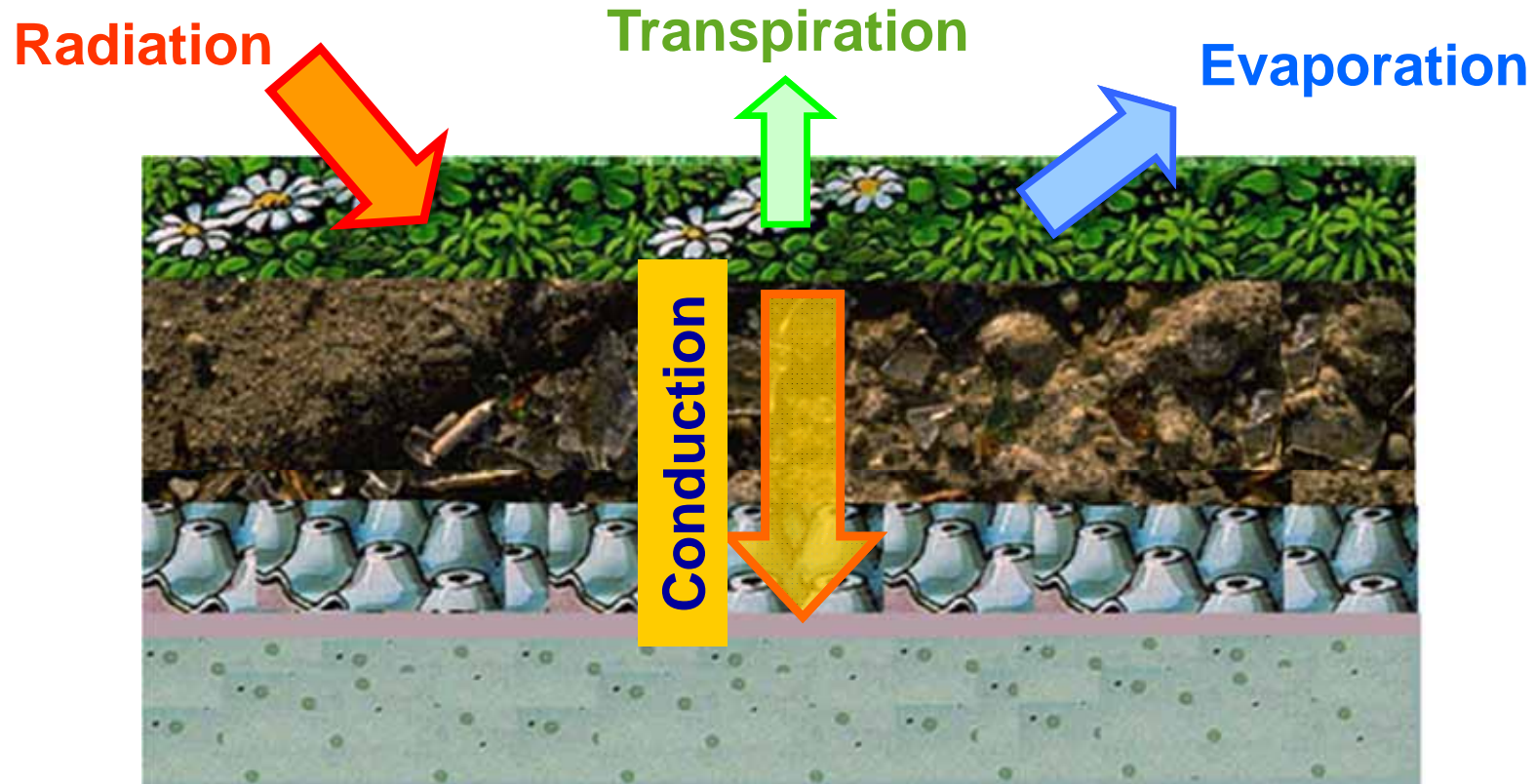


Green roof



Conventional roof

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



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

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

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



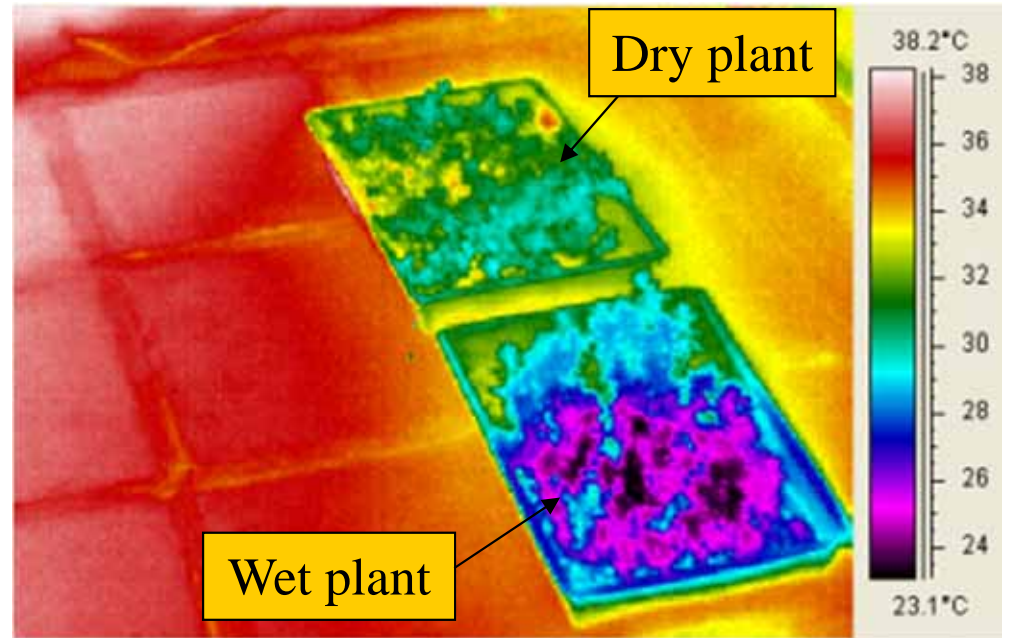
Aluminum trays



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)





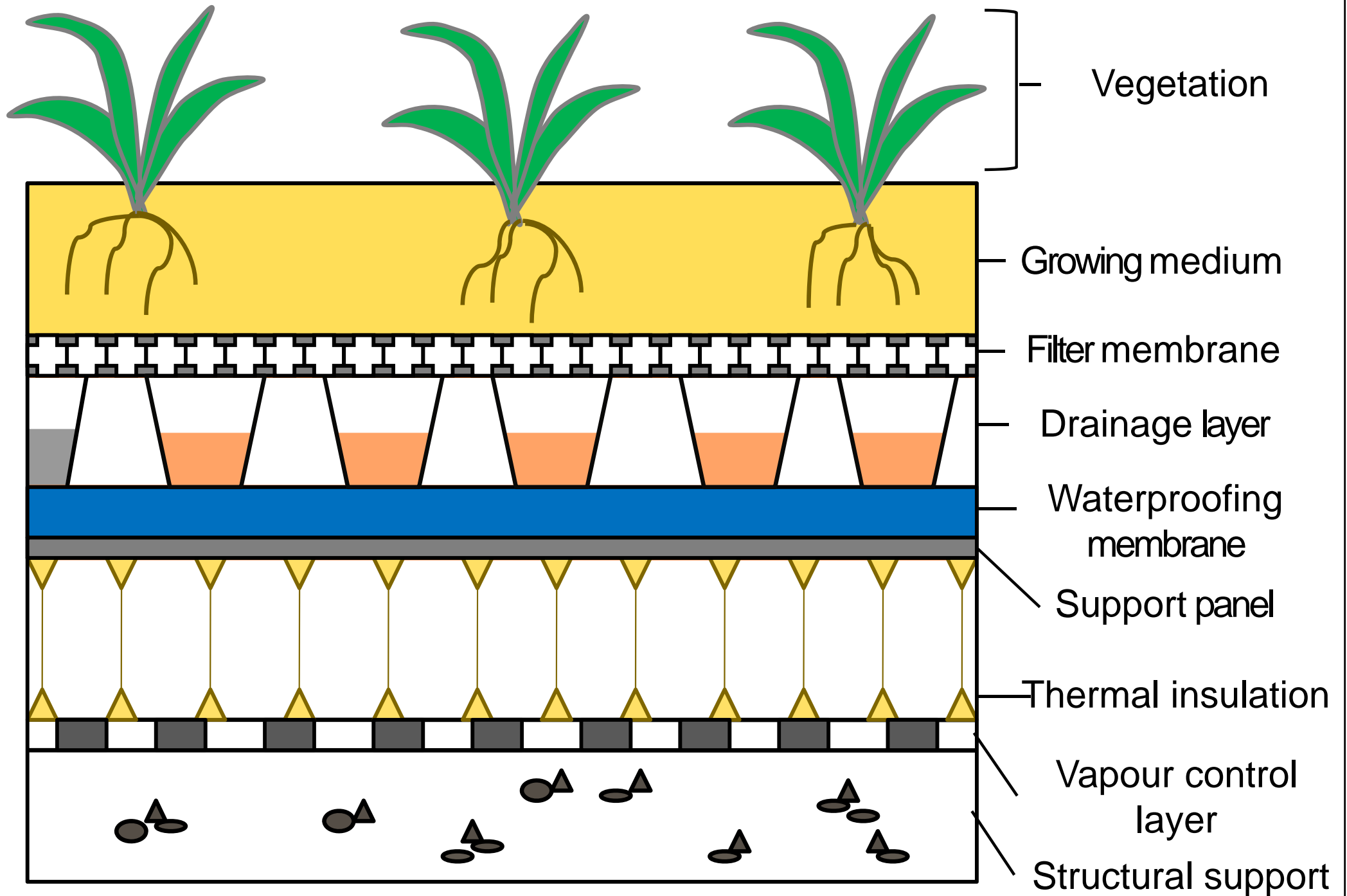


# Introduction 引言

- Current studies 目前的研究:
  - Technical guidelines for green roof systems 屋顶绿化系统的技术指南
  - Technical guidelines for vertical greening systems 垂直绿化系统的技术指南
  - 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
  - HK green roof policy 香港的绿化屋顶政策

# Typical structure of extensive green roof

## 粗放型屋顶绿化的典型结构



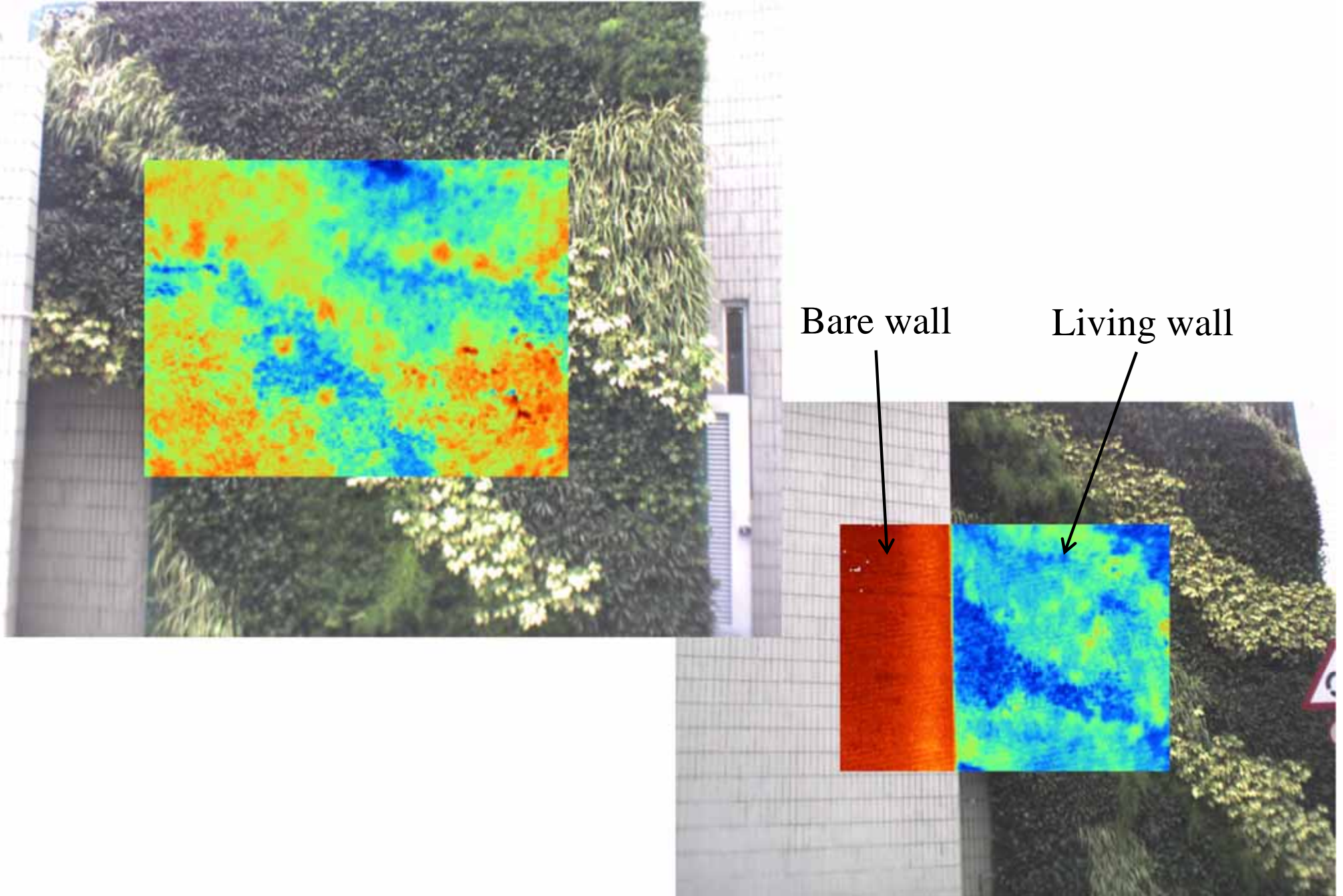
# Integration of green roof and solar energy systems

## 绿化屋顶和太阳能系统的整合



(Photos taken by Dr Sam C M Hui)

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



# 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 绿色基础设施建设
- Possible benefits: 可能的好处
  - 1. Environmental 环境的
  - 2. Economic 经济的
  - 3. Social 社会的



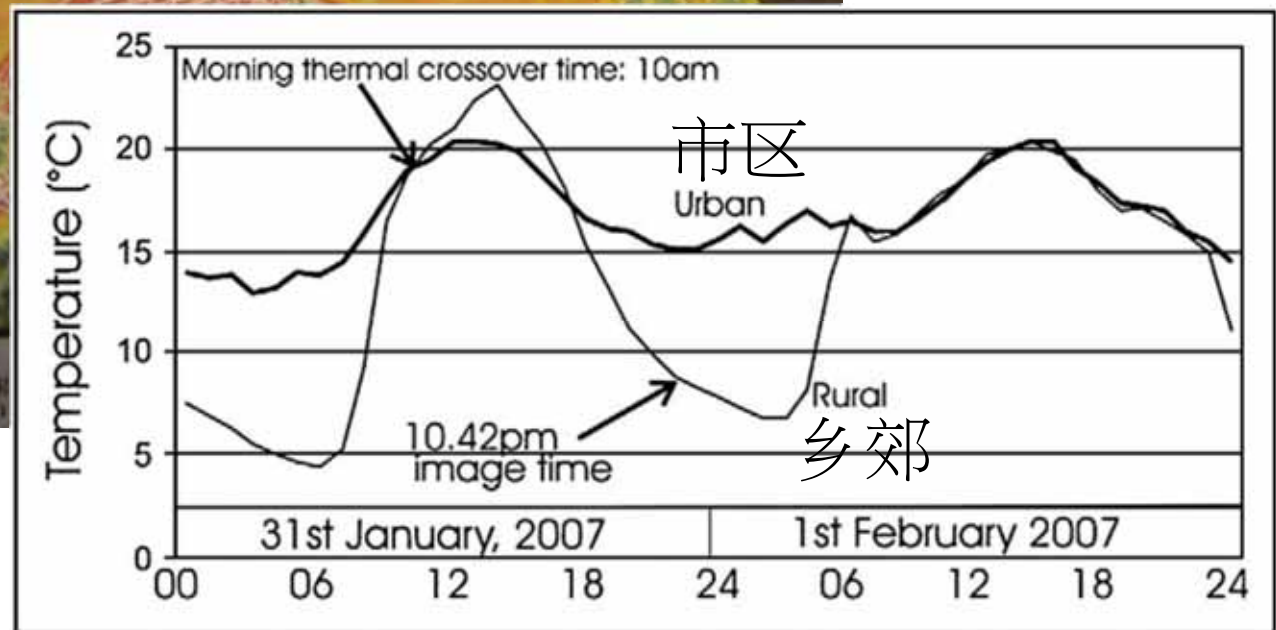
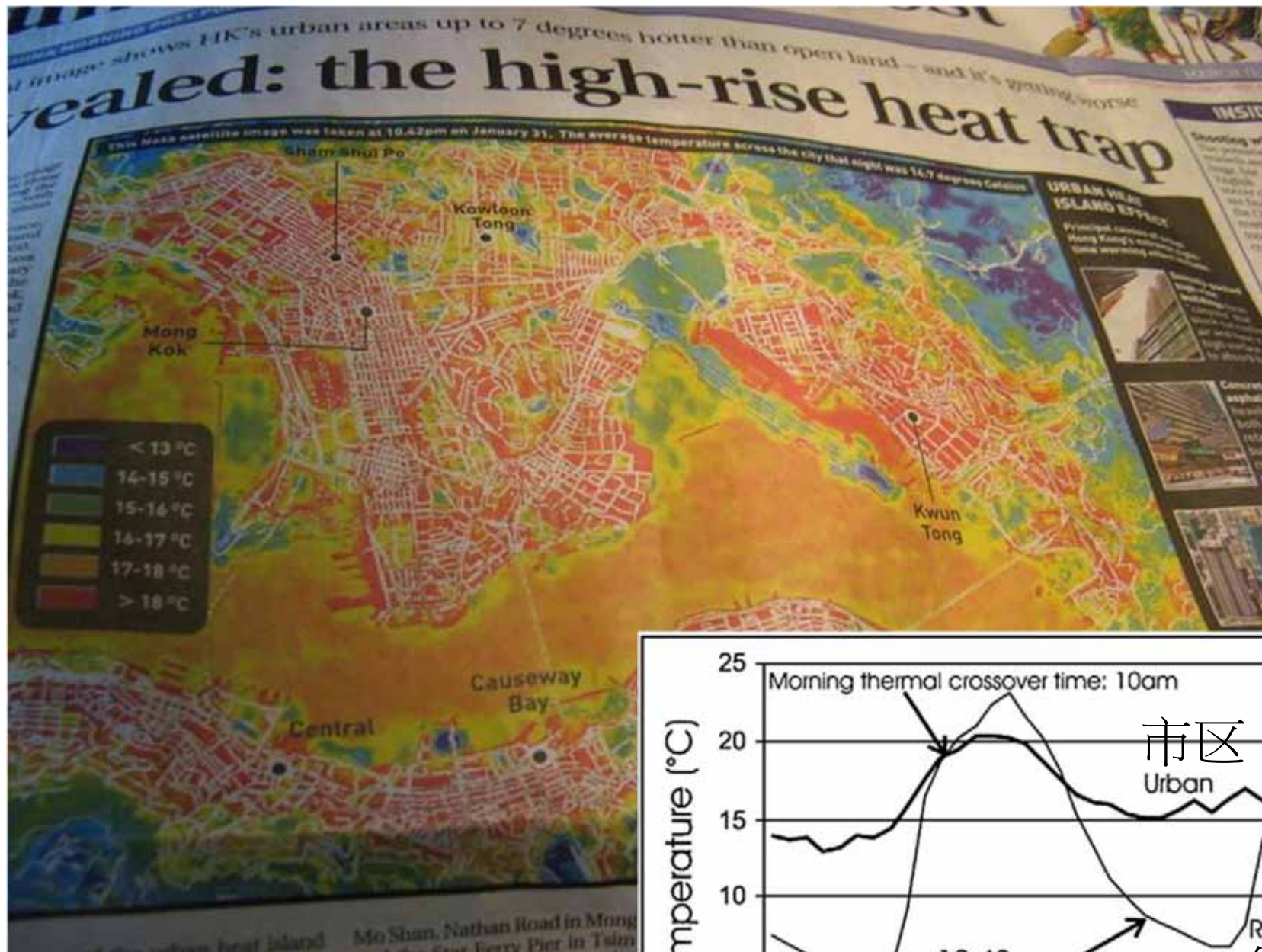
# Potential benefits 潜在的好处



- 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





# Potential benefits 潜在的好处



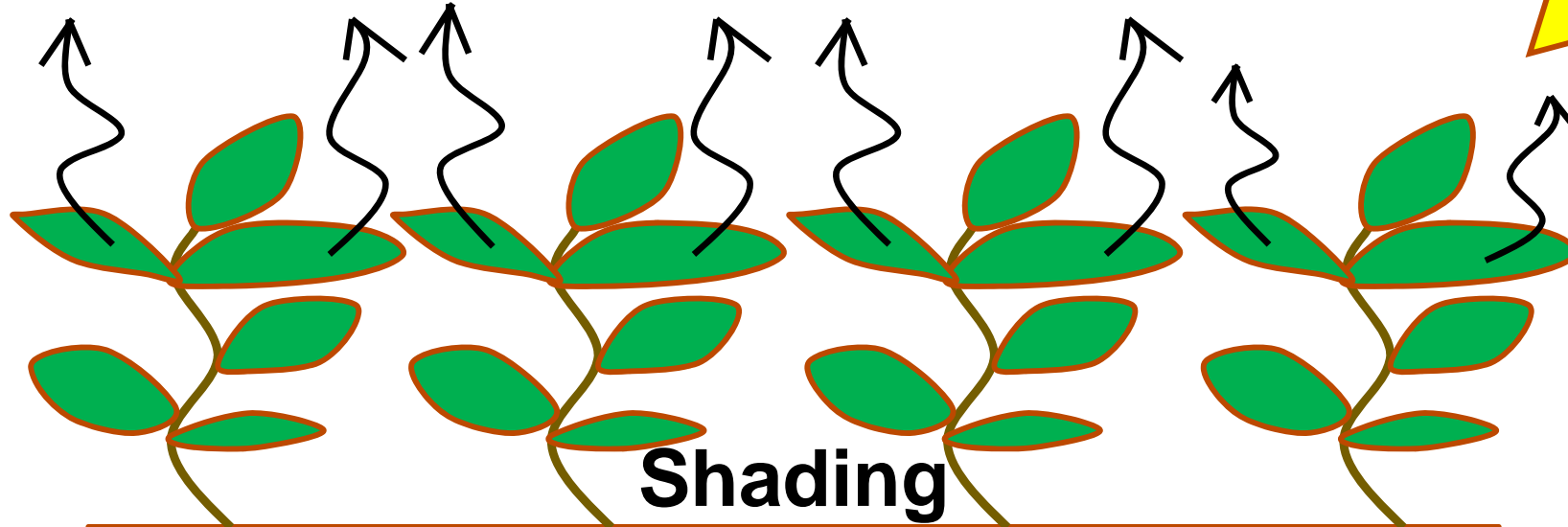
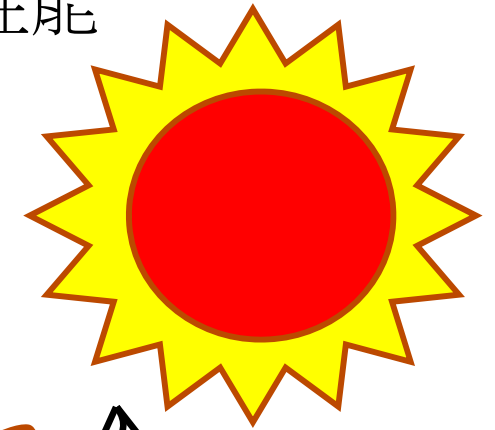
- 2. Economic benefits: 经济的好处
  - - Improve roof durability 提高屋顶的耐久性
  - - Increase roof material lifetime 增加屋顶的寿命
  - - Reduce building cooling load and energy costs  
降低建筑冷负荷和能源成本
  - - Provide open space & increase property value 提供开放空间，可增加物业价值
  - - Green building credit points & image  
绿色建筑评估得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



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

Outdoor

Evapo-transpiration



Shading

Thermal mass

Insulating property

Roof slab

Indoor

# 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

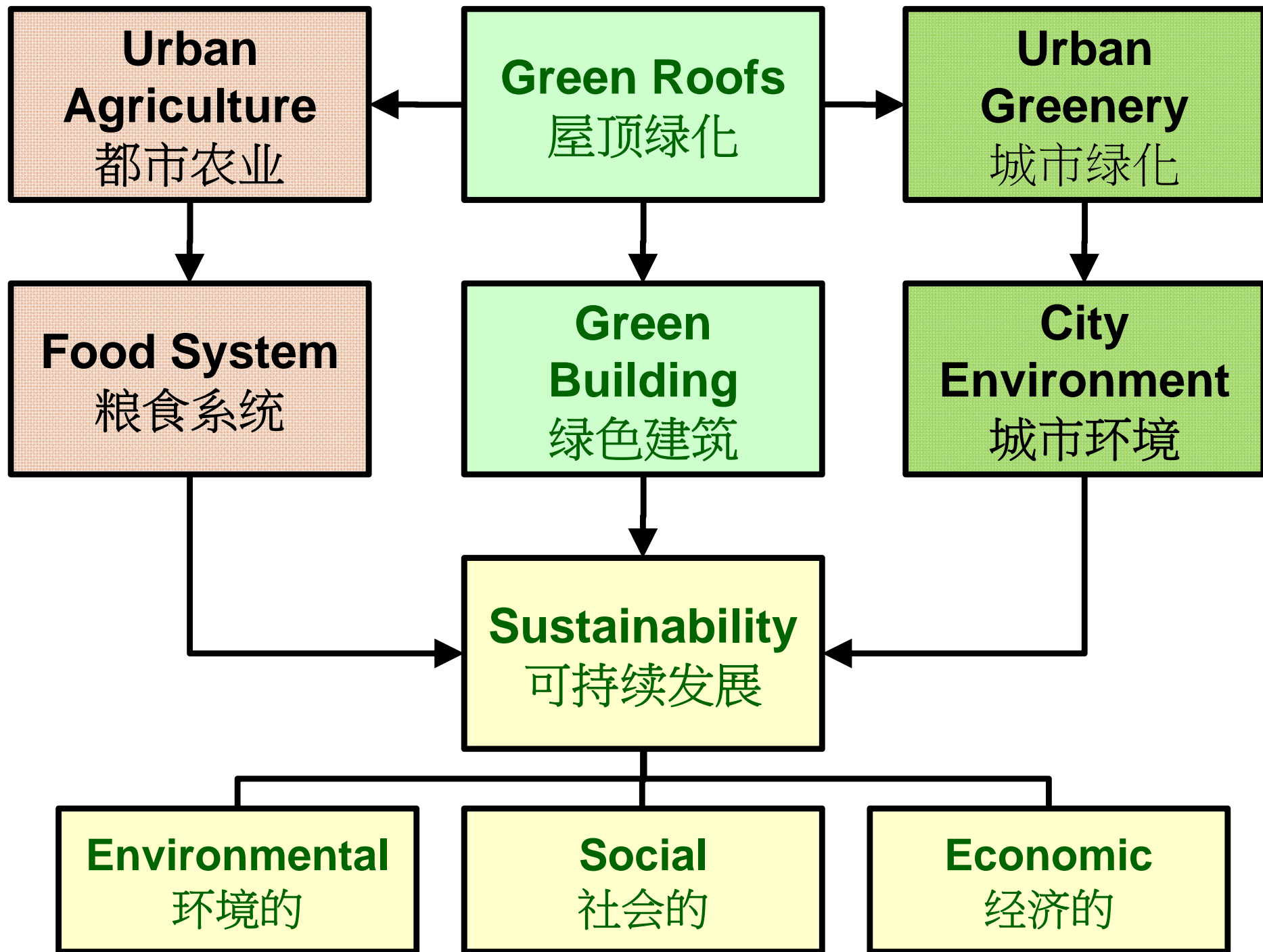


(Source: Ng Yuk Secondary School)

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



(Source: Environment and Conservation Fund)



# 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



# 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



Lowu CSD

(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

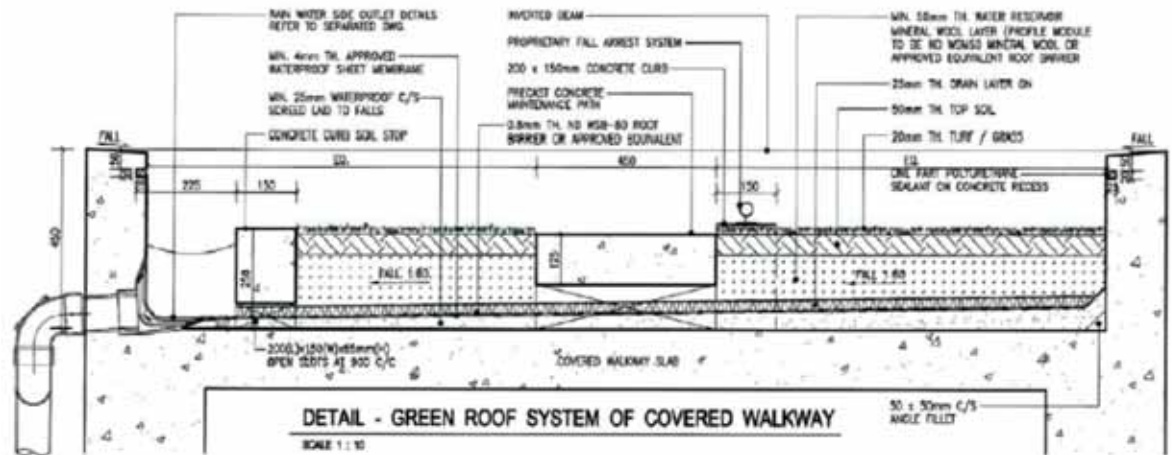
# Roof greening on covered walkway 有盖行人道屋顶绿化



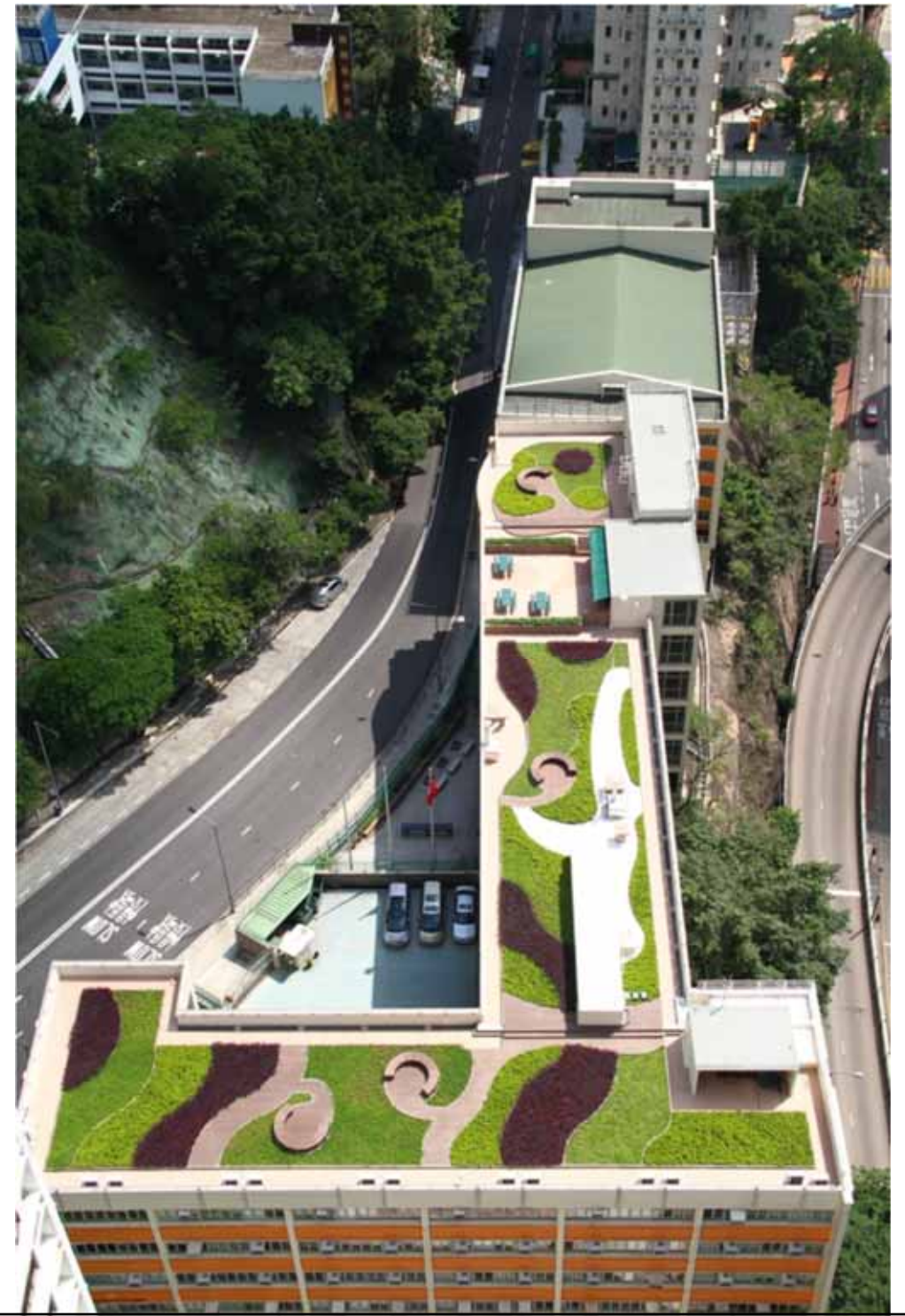
(Photo taken by Dr Sam C M Hui)



(Source: Housing Department, HK)

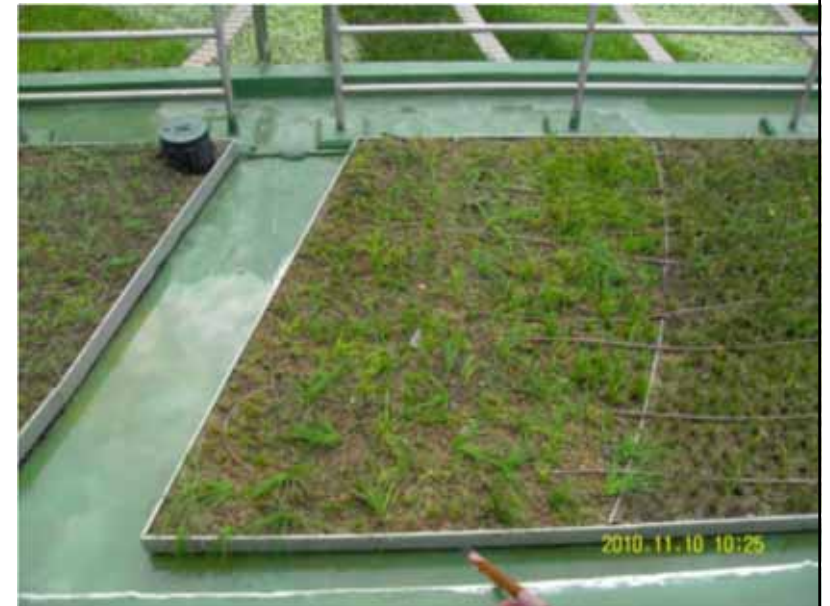


# School green roof project 学校屋顶绿化工程



(Source: Architectural Services Department)

# School green roof project 学校屋顶绿化工程



(Source: Architectural Services Department)

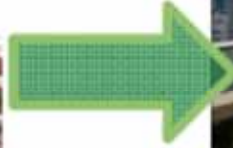
# HKU Centennial Campus 香港大学百周年校园



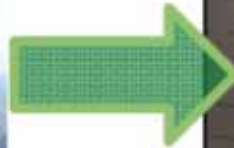
(Photos taken by Dr Sam C M Hui)



# 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

# Kai Tak Cruise Terminal 后德邮轮码头



(Source: <http://inhabitat.com> and Development Bureau)

# 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](http://www.citywalk.com.hk))

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

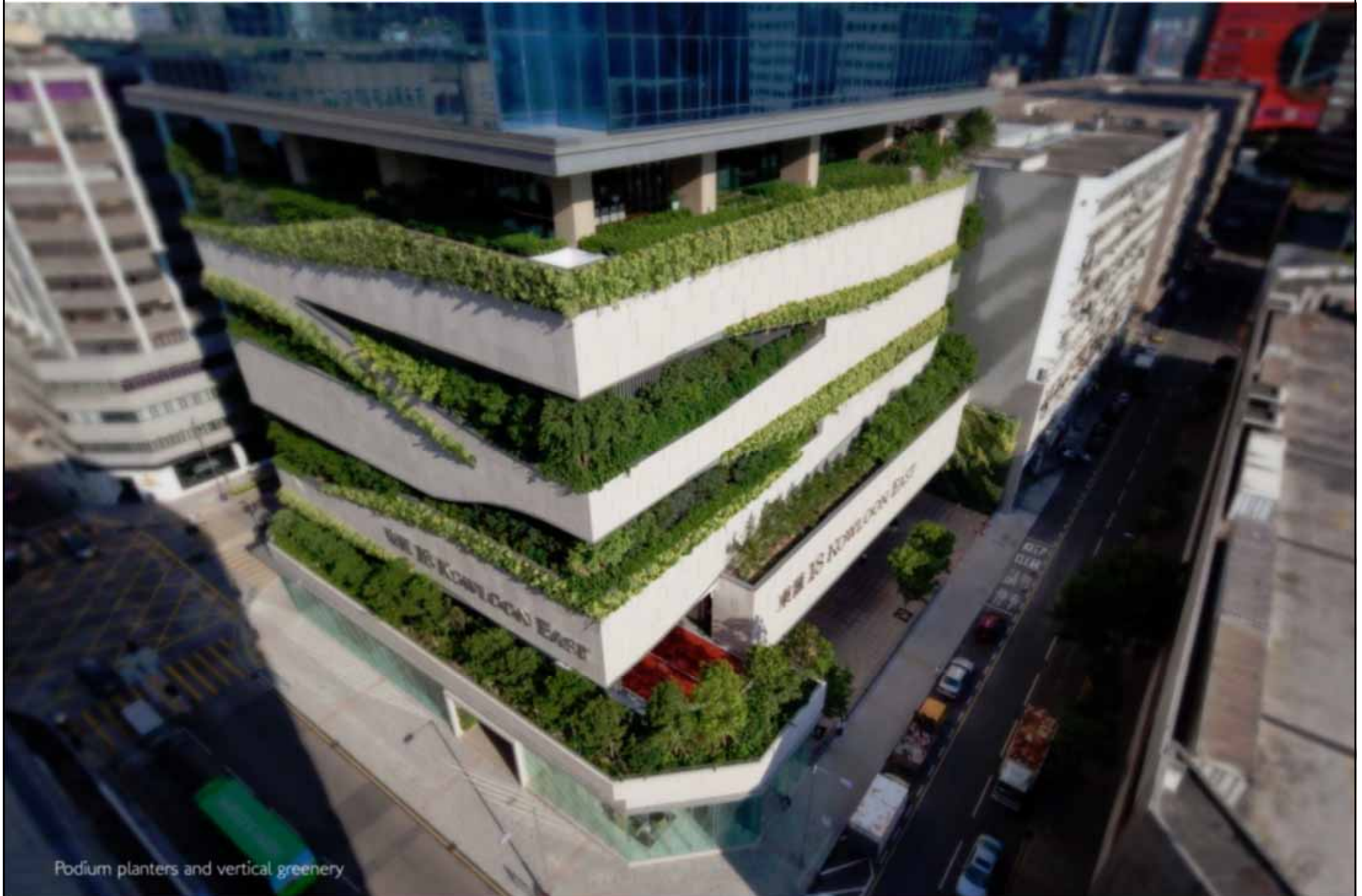


(Source: CityWalk, Tsuen Wan, 荃湾荃新天地, [www.citywalk.com.hk](http://www.citywalk.com.hk))

# 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



Podium planters and vertical greenery

(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



# Government demonstration projects 政府示范项目



For a housing estate



For a school building

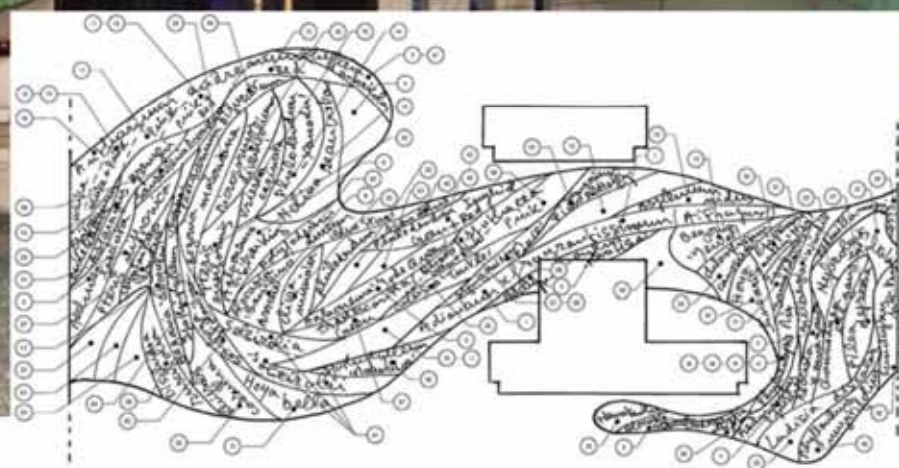
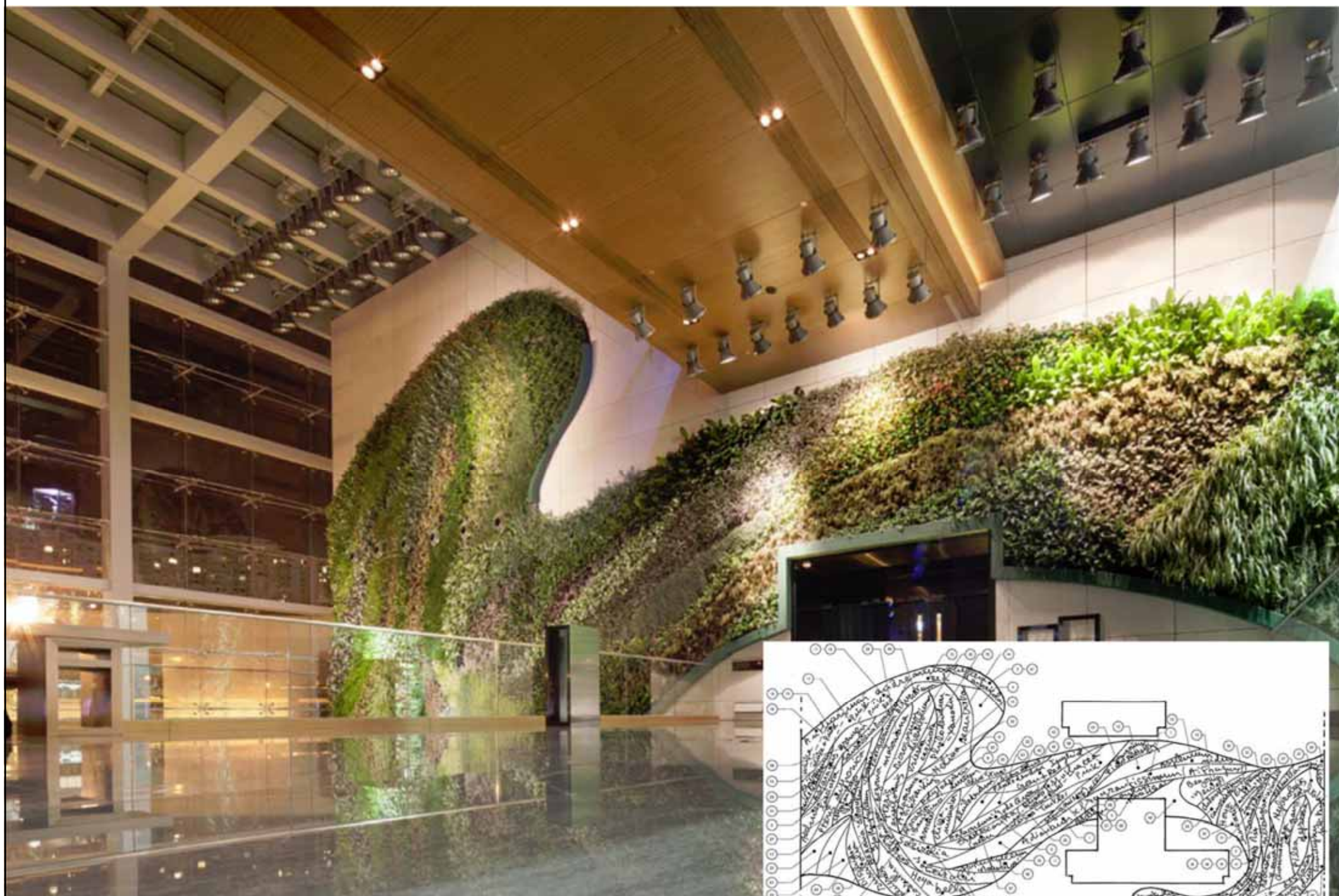


For a government building (EMSD Headquarters)

# A school green wall project 一所学校绿化墙项目



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

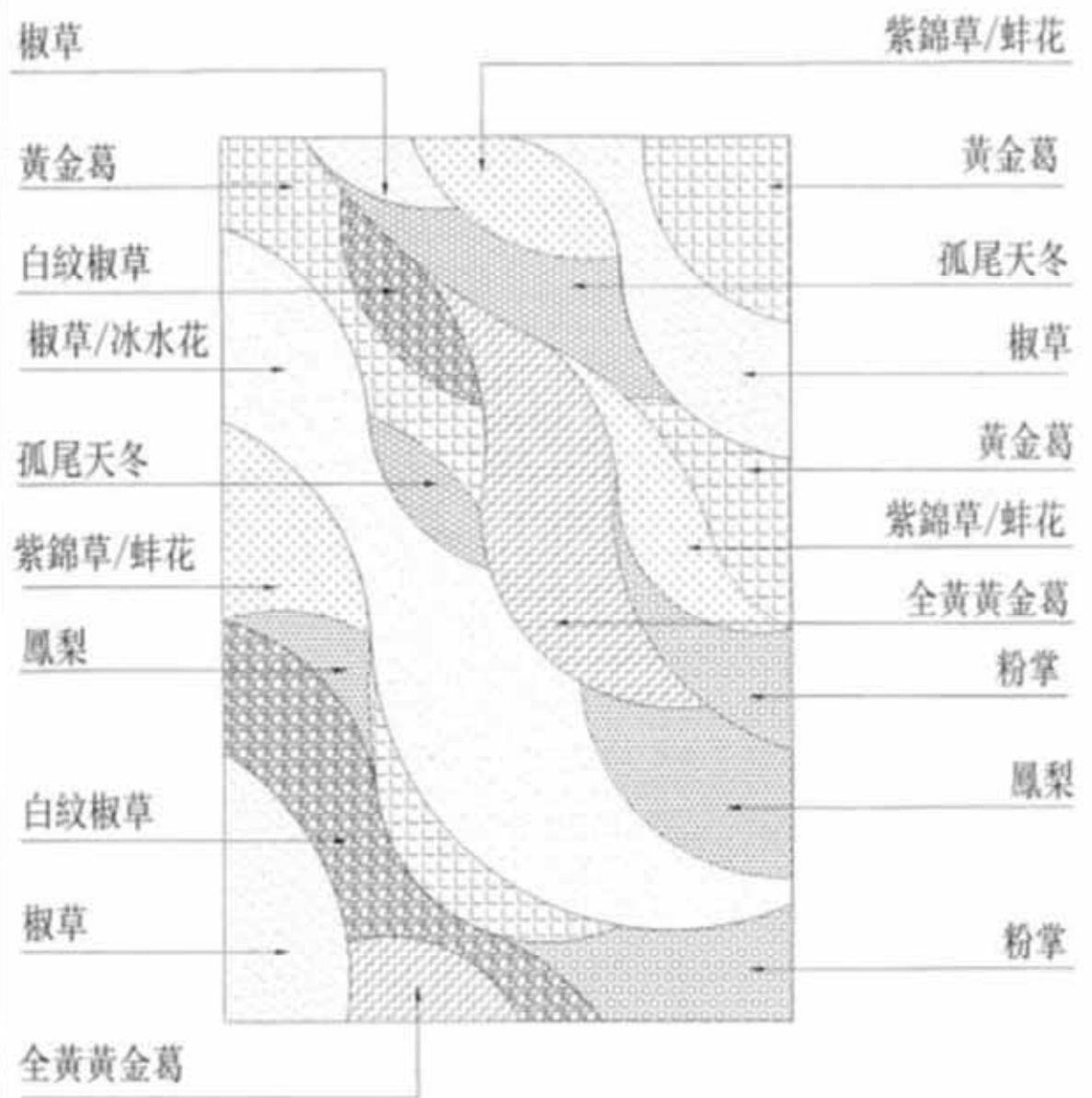


(Source: Hotel ICON)

# Indoor green wall 室内绿化墙



# Indoor green wall 室内绿化墙



(CityWalk 2, Tsuen Wan, 荃湾荃新天地2期)

1 ELEVATION  
Scale: 1:50

# 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)



# Green noise barrier 绿色隔音屏障



(Source: Highway Department, HK)

# Greening on highway structures 绿化公路结构



(Source: Highway Department, HK)

# Greening on slopes 斜坡上绿化



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)

地被植物及蔓生植物  
Groundcover plants  
and trailing plants

備有裝飾設計  
的擋土牆  
Retaining Wall  
with designed  
decorative facing

攀藤植物  
Climbers

樹木  
Trees

地被植物及灌木  
Groundcover  
plants and shrubs

花槽  
Planter

備有種植攀藤小洞或植生  
噴播技術的硬性護面  
Hard surfacing  
with planter holes  
for climbers or  
mulching  
systems

種植攀藤  
小洞  
Planter  
holes for  
climbers

攀藤植物  
Climbers

草及地被  
植物  
Grass and  
groundcover  
plants

灌木  
Shrubs

不可分解防侵蝕護墊  
(如有需要, 加裝鐵網)  
Non-biodegradable erosion  
control mat and, if necessary,  
wire mesh

45°-55°

草、地被植物及攀藤植物  
Grass, groundcover  
plants and climbers

35°-45°

可分解或不可分解防侵蝕護墊  
Biodegradable or non-biodegradable  
erosion control mat

草、地被植物、  
攀藤植物及小樹  
Grass, groundcover  
plants, climbers and  
small trees

灌木  
Shrubs

≤35°

如斜度大於15°, 需加裝  
可分解防侵蝕護墊  
Biodegradable erosion  
control mat for slopes  
over 15°

灌木  
Shrubs

# 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

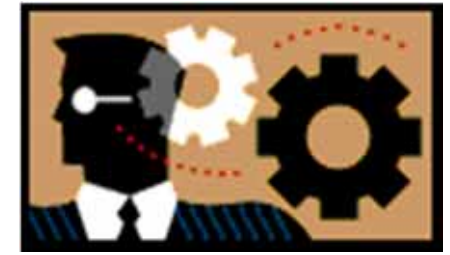
# Green roof on a low-rise building 在低层建筑的屋顶绿化



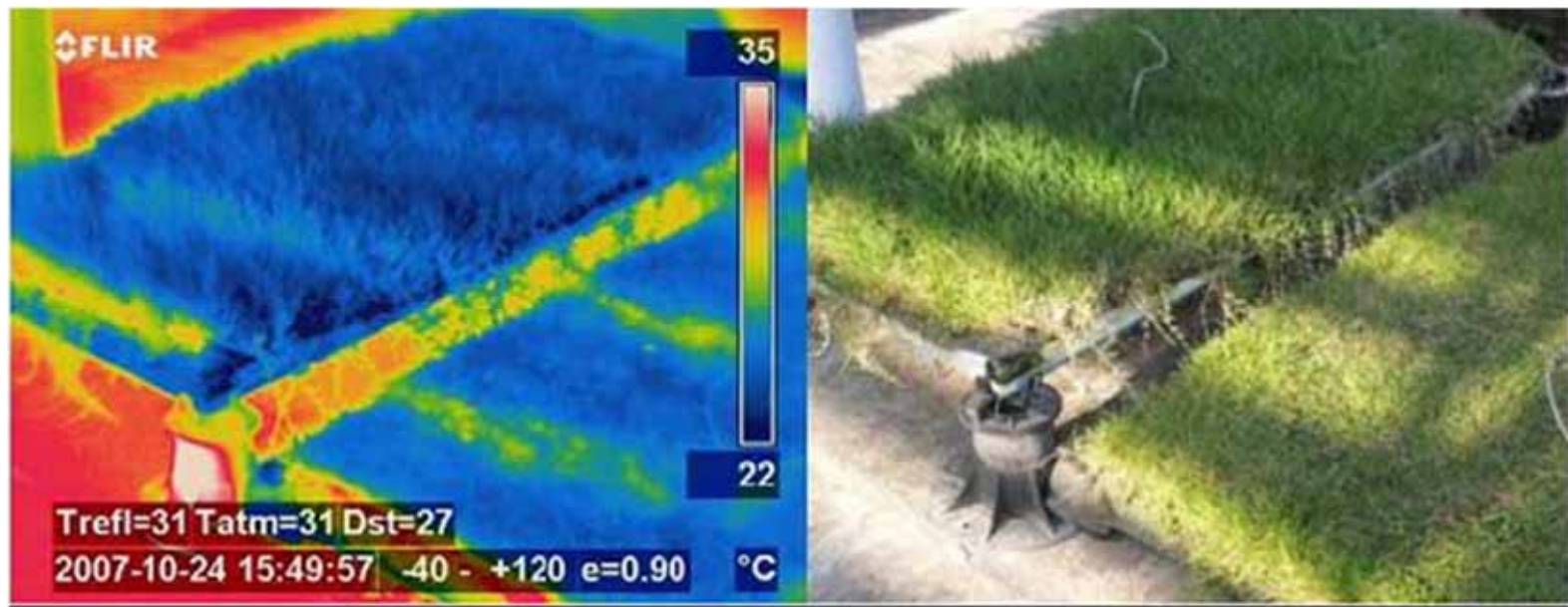
(Source: Hongkong Electric Co., Ltd.)

# 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



Infrared photo for assessing thermal effects  
评估热效应的红外照片

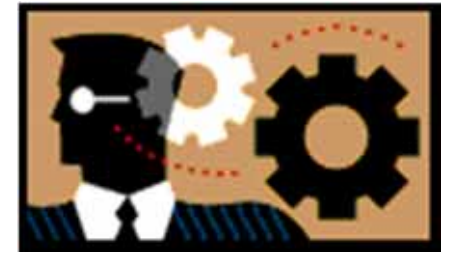


Typical hardy plants (sedums) used for green roofs  
用于绿化屋顶的典型耐寒的景天植物



# 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



# Major considerations

## 主要考虑因素



- Technical guide: 技术指南\*
  - 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

# Development trends

## 发展趋势

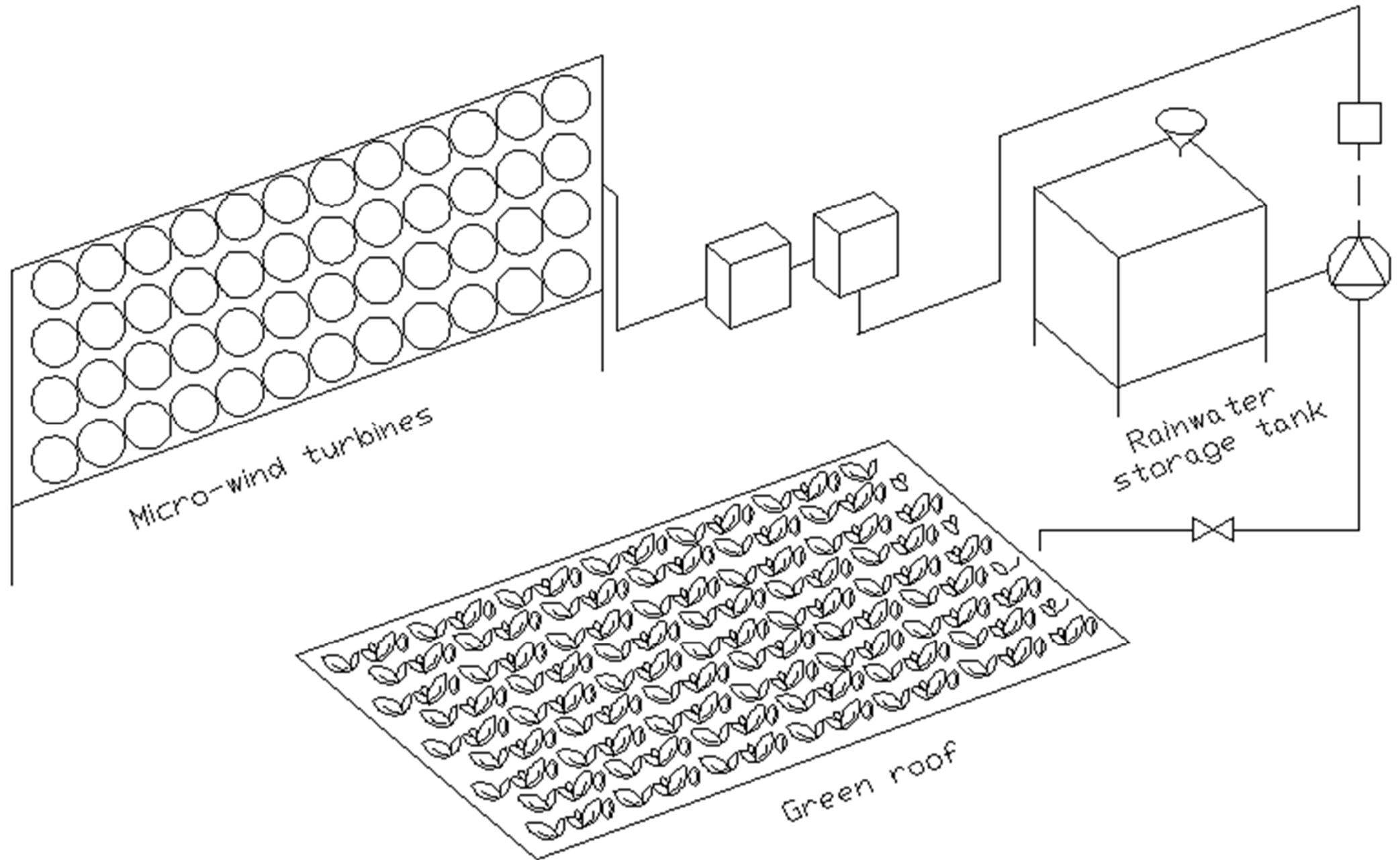


- Sustainable technologies
  - Rainwater harvesting
  - Renewable energy (e.g. solar photovoltaic & wind)
  - Composting (for producing fertilizer)
- Farming and food production
  - Agricultural green roofs
  - Edible living walls



# 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

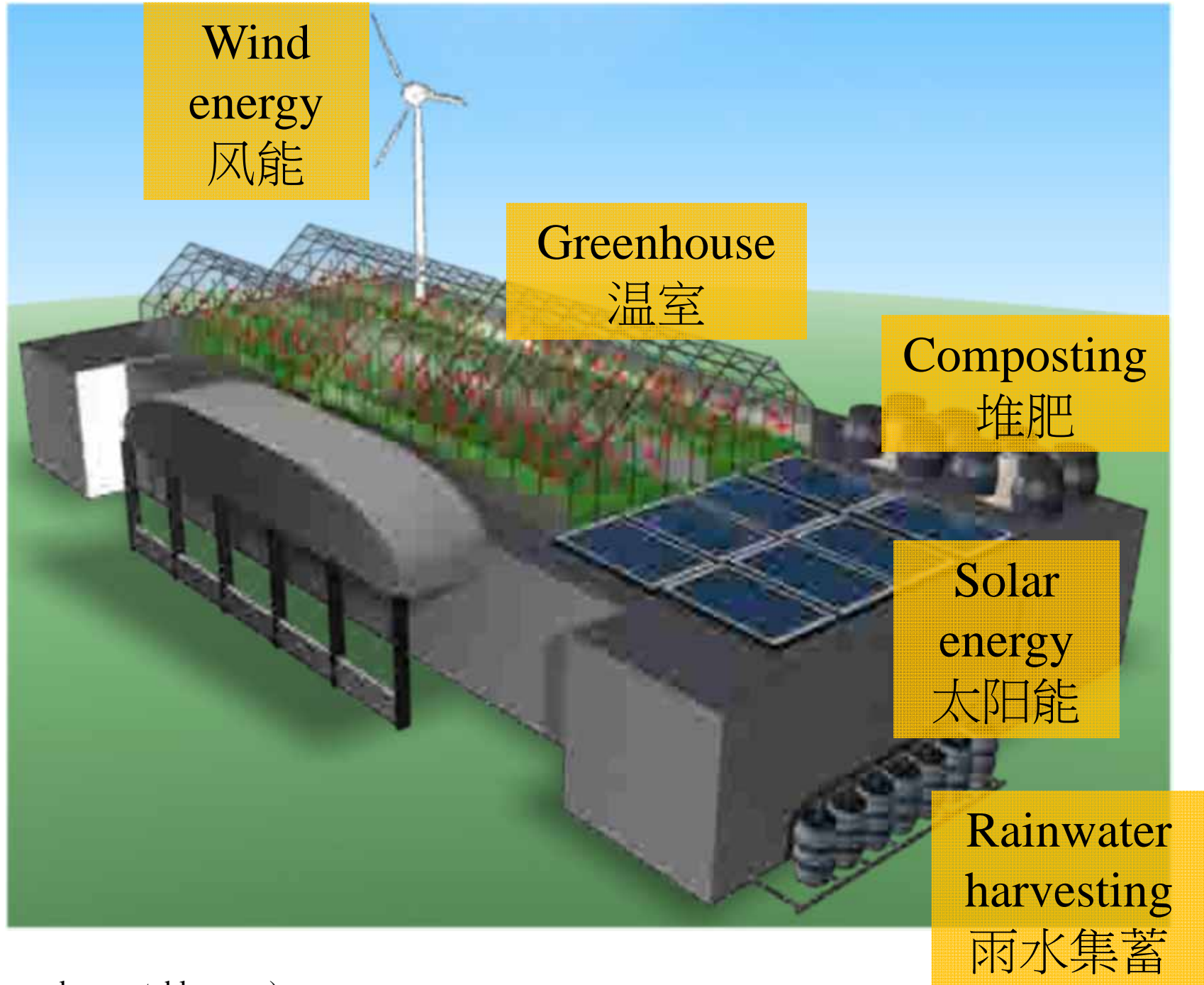


# Integration of green roof and solar energy systems 绿化屋顶和太阳能系

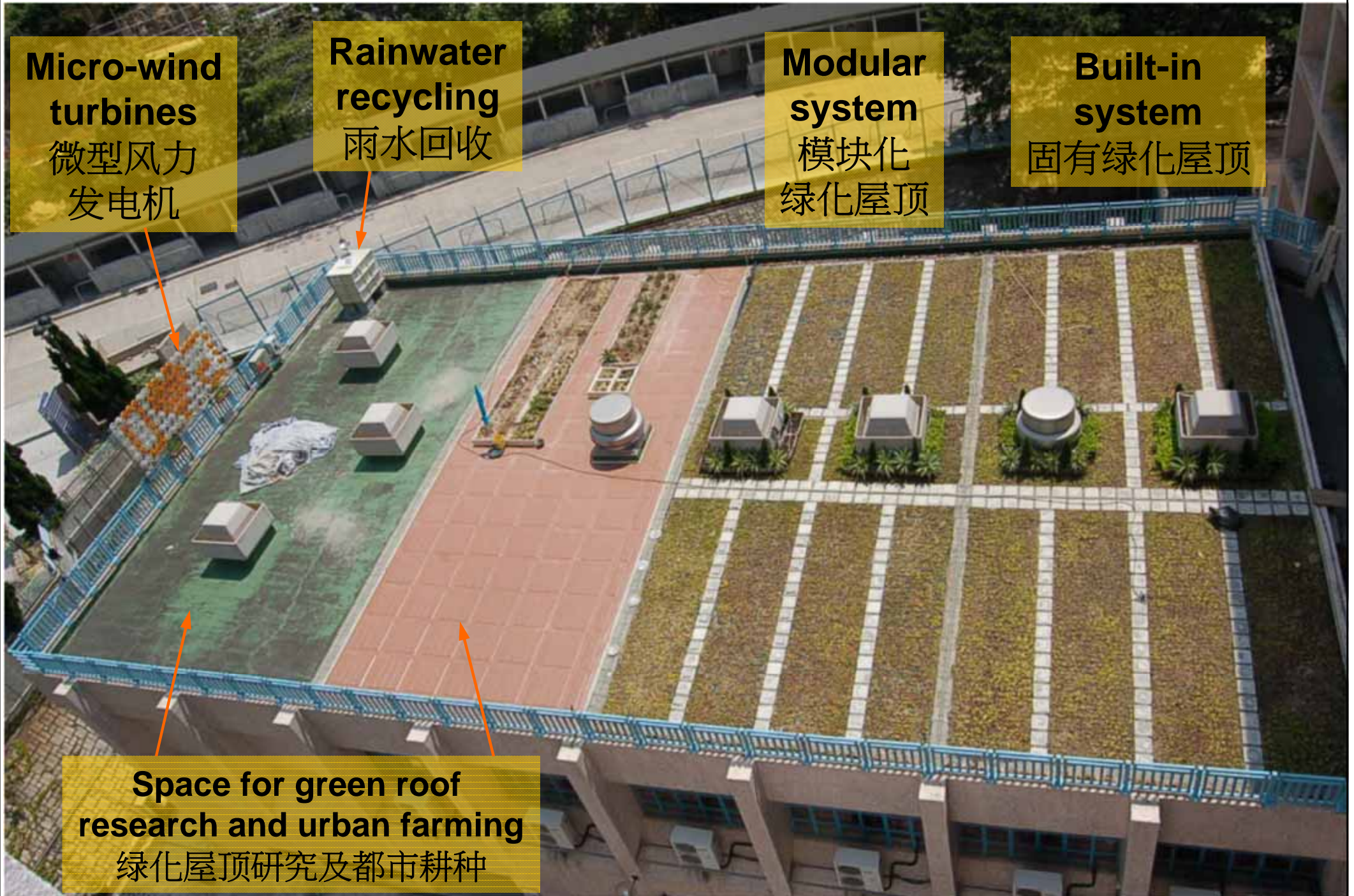


(Source: [www.zinco.de](http://www.zinco.de))

# Sustainable rooftop farming 可持续屋顶耕种



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



**Micro-wind turbines**  
微型风力发电机

**Rainwater recycling**  
雨水回收

**Modular system**  
模块化绿化屋顶

**Built-in system**  
固有绿化屋顶

**Space for green roof research and urban farming**  
绿化屋顶研究及都市耕种

# 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 and 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 )



# 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 多谢 !!



(More information: [www.mech.hku.hk/bse/greenroof/](http://www.mech.hku.hk/bse/greenroof/))