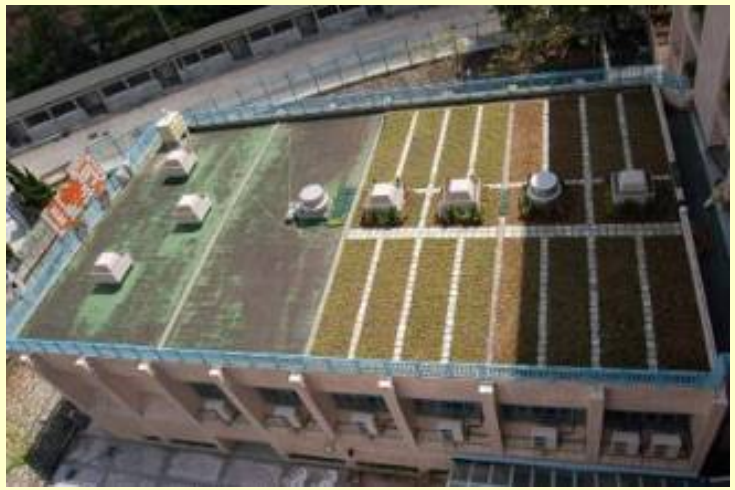
Green Roof Action Project:
Green Roof Experience Sharing Seminar
15 November 2008 (Sat), HKIA Headquarters, 19/F One Hysan Avenue



Research and Development of Green Roof Systems in Hong Kong

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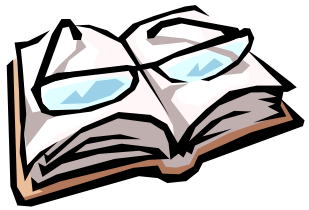
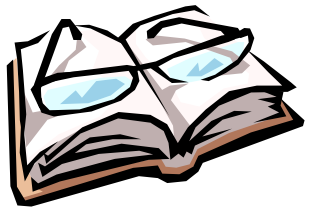
Introduction



- **Green Roof System** – Definitions
  - "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*
  - "Living vegetation installed on the roofs"
  - "Vegetated roof"

Introduction



- Problems that Hong Kong city is now facing
  - Urban heat island
  - Lack of greenery space
  - Stormwater management

- Green roofs can help to mitigate the adverse effects and provide other benefits
  - Bring the nature back to the city
  - Make better use of roof space

Examples of green roofs in Hong Kong

HK Wetland Park

EMSD Headquarters, Kowloon Bay

Parklane, Tsimshatsui

A school in San Po Kwong

(Photos taken by Dr Sam C M Hui)

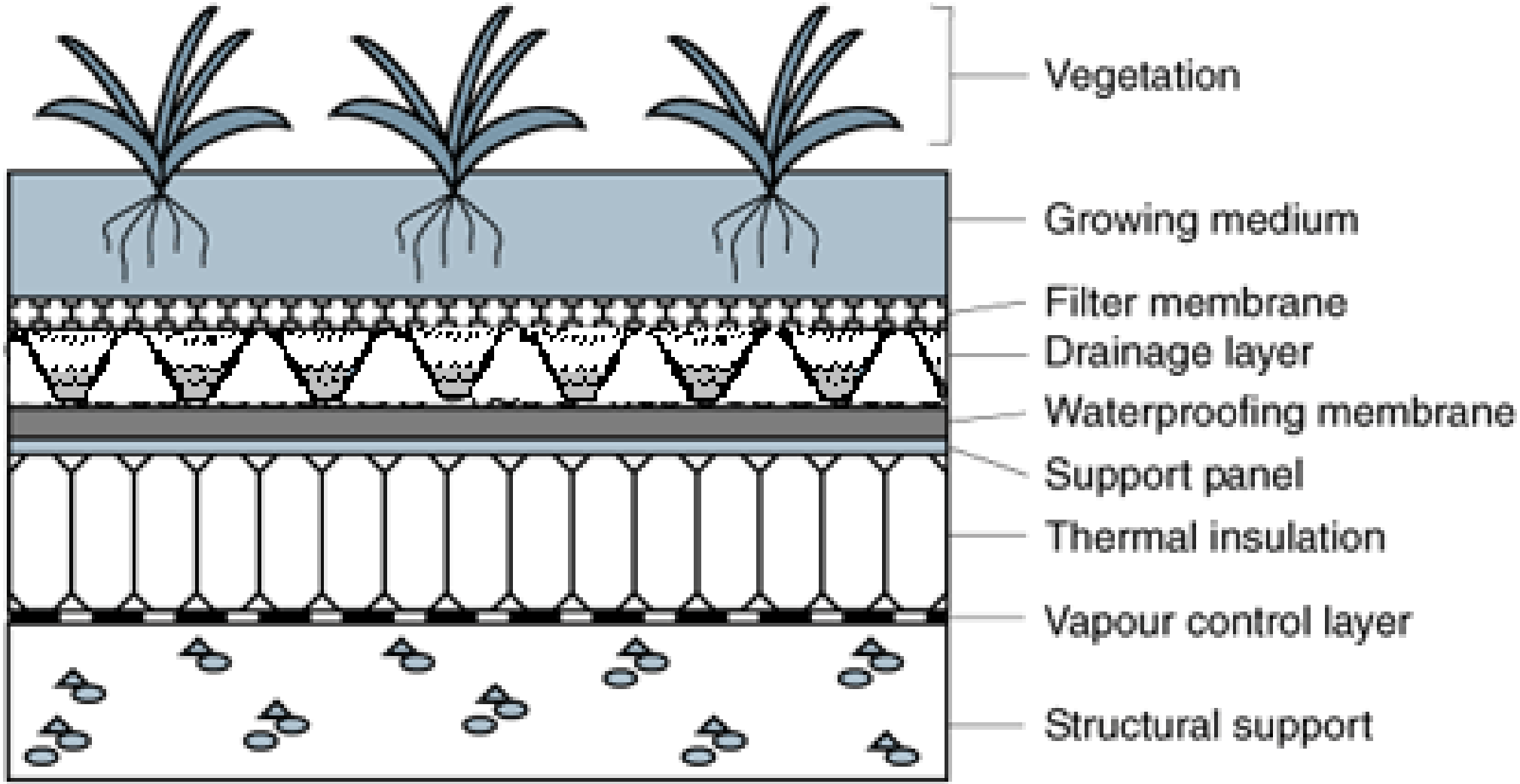
Types of green roof systems

- Major types of green roofs (see Table 1)
  - Extensive
  - Semi-intensive
  - Intensive
- Roof gardens: usually intensive greening with other features such as potted plants, pond, etc.
- Classify green roof systems by basic design:
  - Built-in green roofs
  - Modular green roofs

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



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

Types of green roof systems

- Built-in green roofs
  - 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
  - Prefabricated off-site, pre-grown, with modular design
  - Sub-divided into standard interchangeable parts

Types of green roof systems

- Types of modular green roofs
  - Mat system
    - Vegetated mat, pre-grown, rolled up and transported
    - Very light weight and thin (45 mm)
  - Tray system
    - Most commonly found nowadays
    - Tray containers (e.g. plastic) filled with all elements
  - Sack system
    - Sack paks easily conformed to irregular areas
    - Growing medium in fabric module ready for planting

Vegetated mat system (www.elteasygreen.com)

Tray system (www.liveroof.com)

Sack system (www.greenpaks.com)

Major characteristics of the 3 modular green roof systems

Mat System (Source: Elevated Landscape Technologies, www.elteasygreen.com)	
Size :	1 m^2/module (vegetated area)
Saturated weight :	39 - 73 kg/m^2 (soil depth ≤ 40 mm)
Materials :	High density polyethylene (50% post-industrial recycled materials)
Handling :	Modules must be installed within two days after being palletized
Installation :	Interlocking panels are placed on top of root barrier. Overlap two pockets on the panel and fasten by polyethylene rivets.
Tray System (Source: LiveRoof, www.liveroof.com)	
Size :	0.18 m^2/ module (0.3 m x 0.6 m)
Saturated weight :	73 - 130 kg/m^2 (soil depth = 75-100 mm)
Materials :	100% post-industrial recycled polypropylene
Handling :	18 modules/pallet, 54 pallets/truck
Installation :	Ergonomically designed modules can be installed by just one person. They are placed on root barrier and needs to be watered immediately after installation.
Sack System (Source: Green Paks, www.greenpaks.com)	
Size :	0.48 m^2/module
Saturated weight :	83.2 kg/m^2 (soil depth = 100 mm)
Materials :	Woven fabric knitted of high density polyethylene
Handling :	42 modules/pallet, 20 pallets/truck
Installation :	Modules can be stored prior to installation. They are placed on root barrier and cut slits in the fabric module to insert plant plugs or seeds.

Potential benefits

- Major aspects
  - Visual and aesthetic
  - Ecological
  - Local microclimate
  - Thermal performance
  - Amenity

- Benefits for the community (public)
- Benefits for building owners & users (private)

Table 2. Public and private benefits of green roof systems

Public benefits:	**Private benefits:**
- Mitigate urban heat island	- Increase roof life expectancy
- Reduce dust and pollutant levels	- Reduce noise levels
- Stormwater retention	- Enhanced thermal insulation
- Natural habitat for animals/plants	- Heat shield
- Cities and landscapes	- Better use of space
- Nature look (aesthetic)	- Reduced risk of glare for surrounding buildings

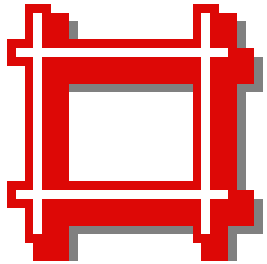
Potential benefits

- Other possible benefits of green roofs
  - Urban farming (e.g. growing vegetables, herbs)
    - Make best use of roof space; may be organic
  - Education (environmental, scientific, liberal study)
    - Integrated with school curriculum
  - Community and social functions
    - Exercises & hobbies for children, adults & elderly
  - Healing landscape (e.g. horticultural therapy)
    - Sensory, meditation effects; manage emotion/stress

Urban farming & education

Horticultural therapy & social functions

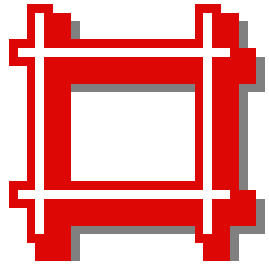
Our Research Studies



- Our green roof research aims to develop:
  - Knowledge of green roof technology
  - Assessment and design guidelines
  - Practical information for green roof application
- Multi-disciplinary approach
  - Engineering
  - Architecture
  - Construction

(* Further info: www.hku.hk/bse/greenroof/)

Our Research Studies



- Research studies done (BEng & MSc projects):
  - Energy and environmental performance
  - Cooling and air quality effects of green roofs
  - Modular green roof systems
  - Thermal modelling (green roofs & living walls)
  - Life cycle assessment
- On-going research:
  - Green roofs for mitigating stormwater problems

Green roof research at a construction site office (2002-2006)

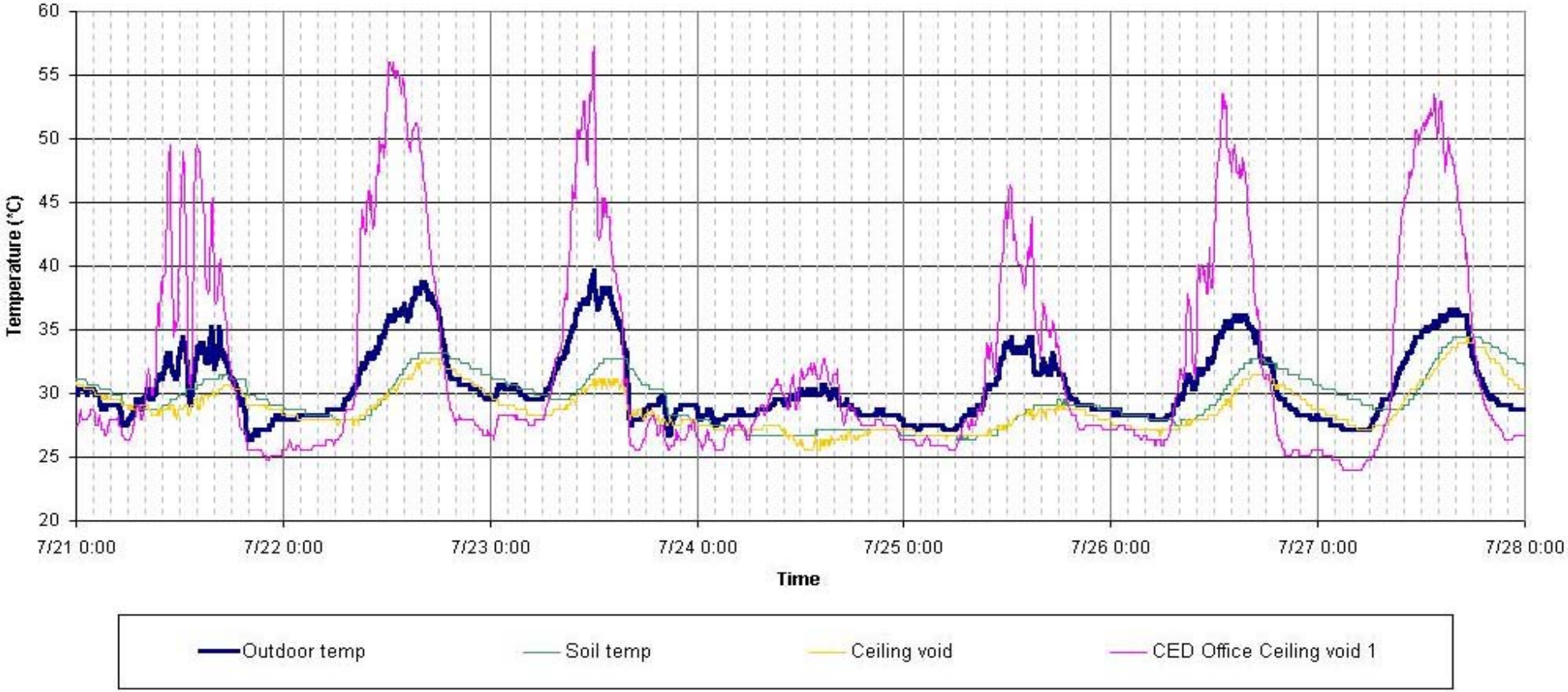
Green site office

Modular design

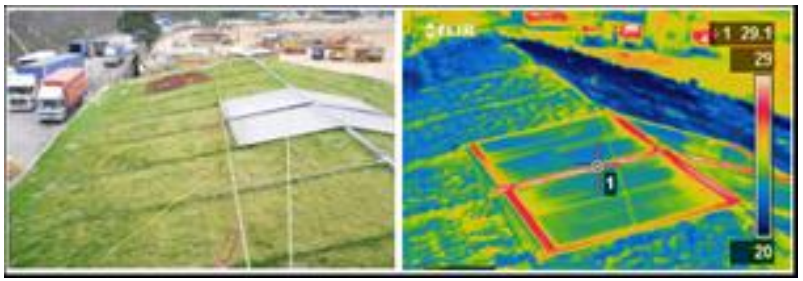
Green site office and typical site office

Water sprinkler

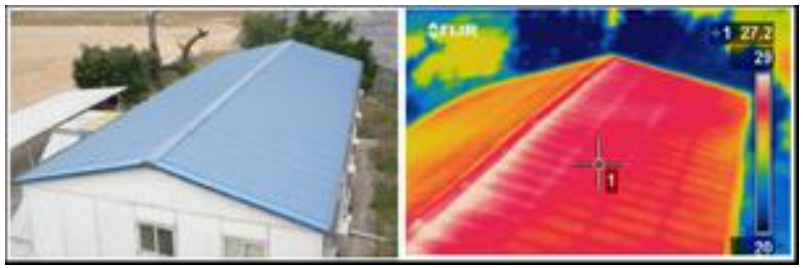
Green roof research at a construction site office (cont'd)



Infrared pictures:



Green roof



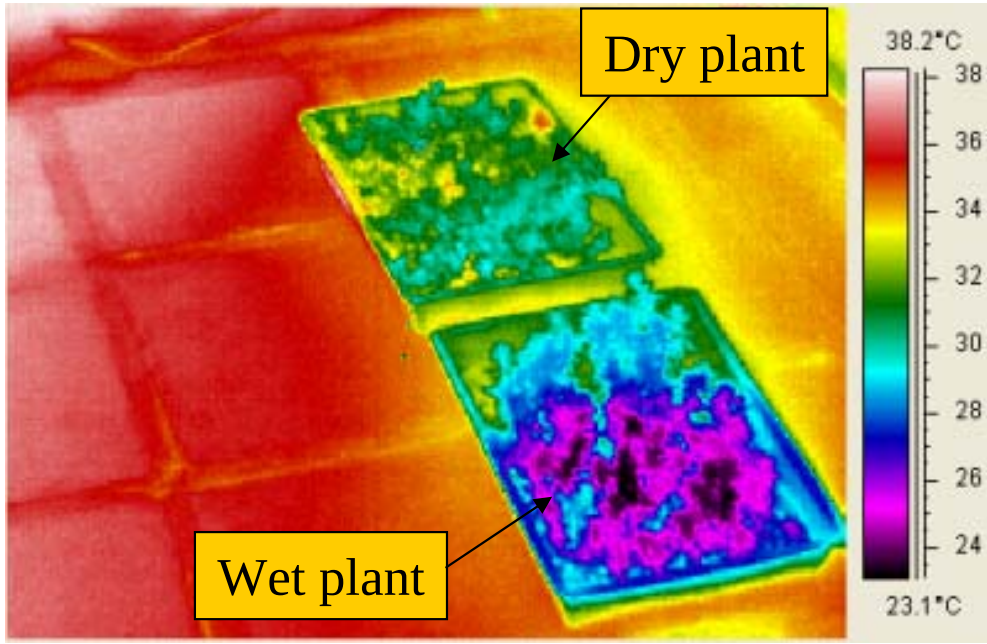
Conventional roof

Study of modular green roof systems (2007-2008)

Aluminum trays

Wooden boxes

Plastic trays



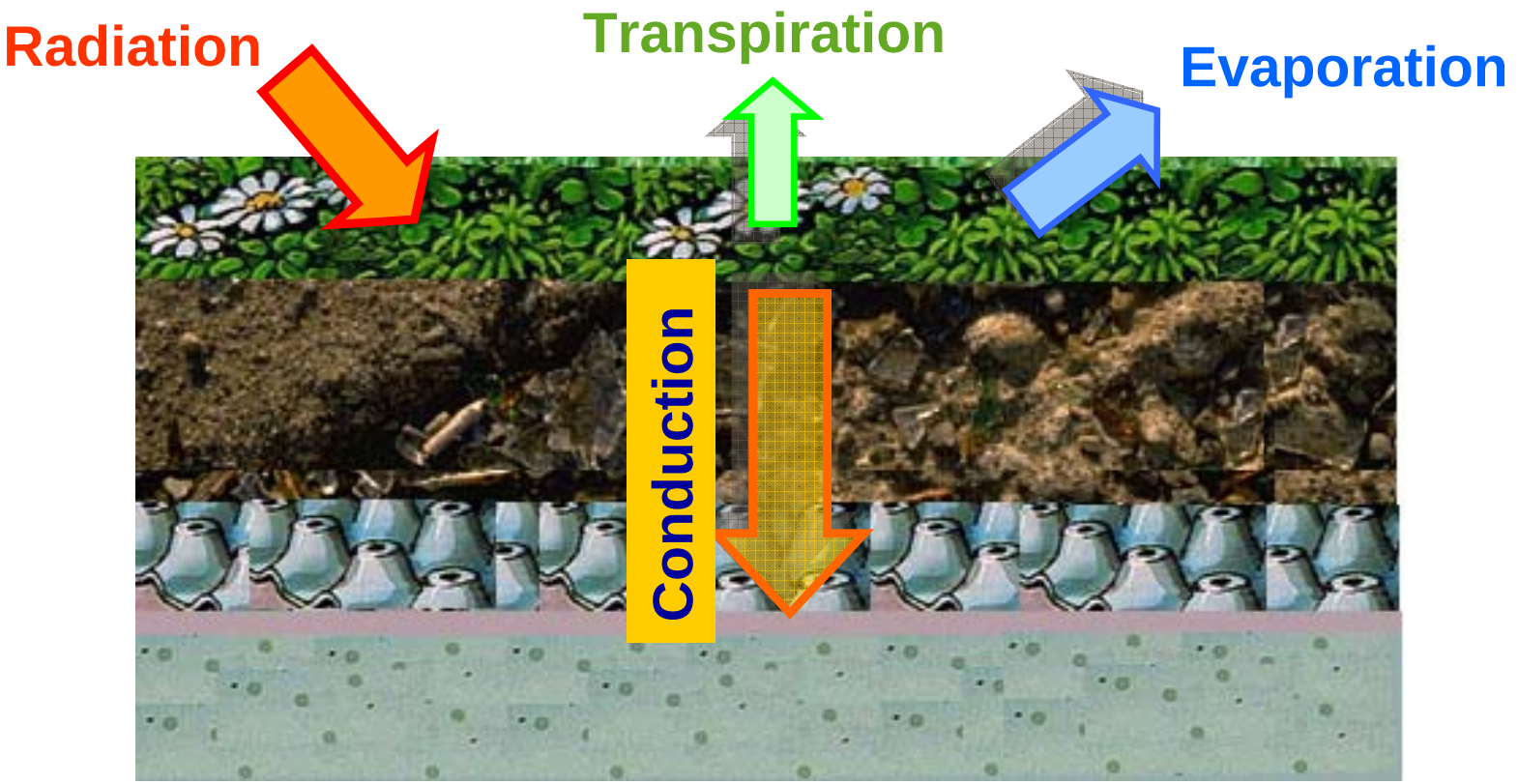
Plastic trays (infrared photo)

Weight assessment

Temperature measurements

Study of typical hardy plants (sedums)

Thermal modelling of green roofs



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

Major findings of life cycle analysis (LCA) for green roofs

Impact Category	Unit	Extensive	Intensive
Abiotic Depletion	kg Sb eq	101250	97142
Global Warming (GWP100)	kg CO_2 eq	12762781	12247011
Ozone Layer Depletion	kg CFC-11 eq	0	0
Human Toxicity	kg 1,4-DB eq	3599753	3442516
Fresh Water Aquatic Ecotox.	kg 1,4-DB eq	517670	495073
Marine Aquatic Ecotoxicity	kg 1,4-DB eq	1.64×10^{10}	1.57×10^{10}
Terrestrial Ecotoxicity	kg 1,4-DB eq	59308	56716
Photochemical Oxidation	kg C_2H_4	2625	2516
Acidification	kg SO_2 eq	72061	69060
Eutrophication	kg PO_4--- eq	4628	4438

(* The data are taken from the results of a MSc project carried out by Ms. Lui Shiu Ting Elsa.)

Hong Kong situation

- Main driving forces:
  - Government, building designers & green groups
- Major barriers:
  - Limited roof areas and space (high-density & high-rise buildings)
  - Economic factors (hard to measure the benefits)
  - Lack of knowledge & design guidelines
  - Lack of government policy & standards

Hong Kong situation

- Designing green roofs in Hong Kong
  - High-rise buildings (very limited roof area)
    - More effective to apply green roof to medium- or low-rise buildings/structures
    - Occupants from surrounding can enjoy the green roof
  - Existing buildings (often have constraints on roof structural loading & space)
    - Select extremely light-weight green roof systems
    - Inaccessible roof: use extensive green roof
    - Accessible roof: build roof garden or hybrid systems

Hong Kong situation

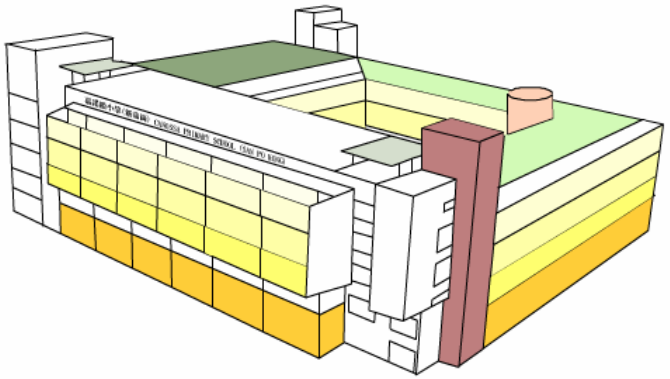
- Important climatic factors in Hong Kong
  - Typhoons
    - May blow away vegetation & soil. Modules & plants must be well secured and protected
  - Heavy rainfalls
    - Drainage and hygiene (mosquito) issues
  - High temperature – affect some plant species
  - Strong sunlight
    - Solar & UV effects on green roof materials & components

Hong Kong situation

- Issues to consider when applying green roofs:
  - Position and orientation of the roof
  - Height of the roof above ground
  - Roof pitch (flat or slopped)
  - Weight limitation of the roof
  - Preferred planting
  - Levels of maintenance (usually low is better)
  - Possibility of rainwater recycling
  - Sustainability of components (recycled materials)

Hong Kong situation

- Application studies carried out
  - School buildings
  - Construction site offices
  - Government buildings



- Why we are interested in <u>school buildings</u>?
  - They have good potential for applying green roofs
  - Can demonstrate many benefits & issues
  - Can influence the local community & students
  - Can integrate/serve many education purposes

Research & development of green roofs for a primary school

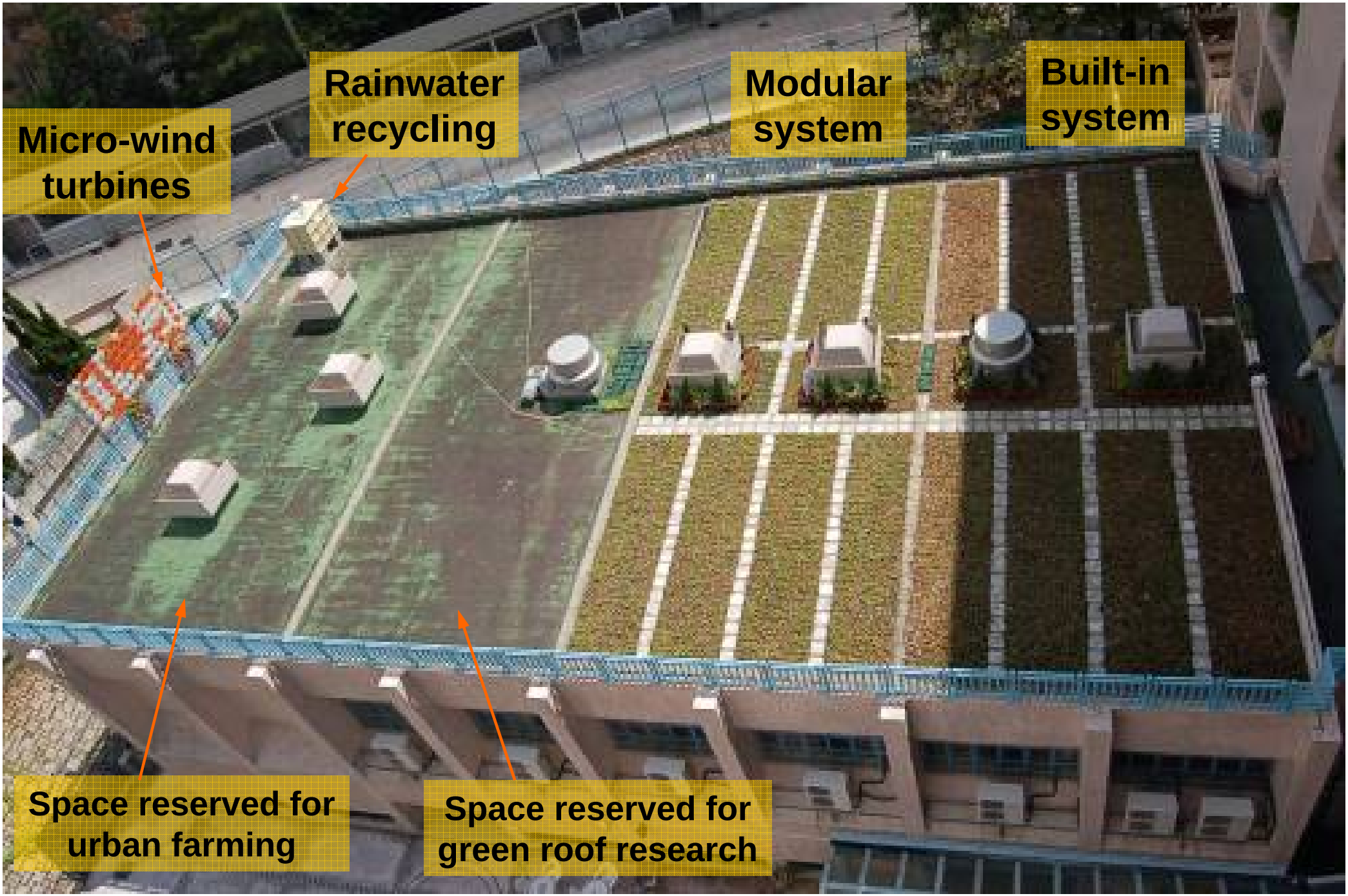
Pilot study:
Roof of a function room
Roof area = 58 sq.m
Soil depth = 150 mm

Studies on thermal performance & sedum

Pilot project:
Roof of an assembly hall
Roof area = 530 sq.m
Soil depth = about 40 mm

Studies on modular system & life cycle performance

A green roof project with integrated systems in a primary school



Practical problems observed in Hong Kong

An award-winning (sustainable design) government project in N.T.
-- green roof become “brown roof”
-- possible reasons: poor maintenance & choice of plants

A built-in green roof system in a school building
-- death of sedum vegetation
-- possible reasons: weeding, birds, improper choice of sedum

Practical problems observed in Hong Kong (cont'd)

A green roof system in a school building
-- difficulty of access
-- possible reason: the existing roof is not designed for easy access

Our laboratory testing of green roof plants and components
-- death of plants
-- possible reasons: insufficient soil, poor air quality, choice of plants

Conclusions

- Green roofs can provide many benefits to mitigate environmental problems in HK
- More efforts are needed to develop design guidelines & practical experience for green roof application
- Assessment guidelines & checklist are now being developed in our research at HKU
  - Project goals
  - Design requirements
  - Maintenance issues
  - Cost estimation

Green roofs as a sustainable element in our minds.

Thank You

謝 謝！