

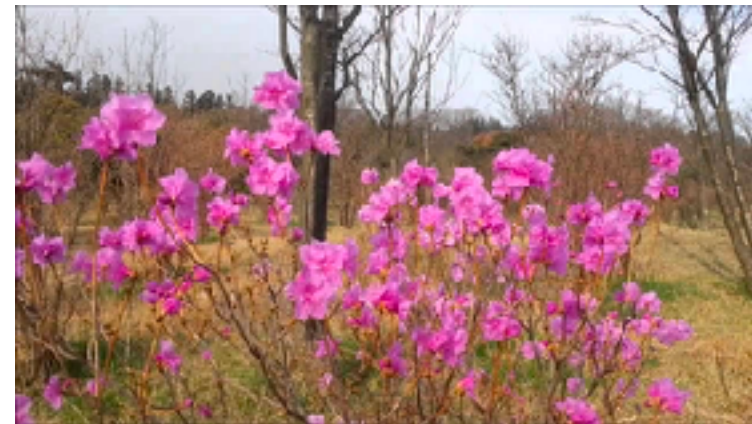
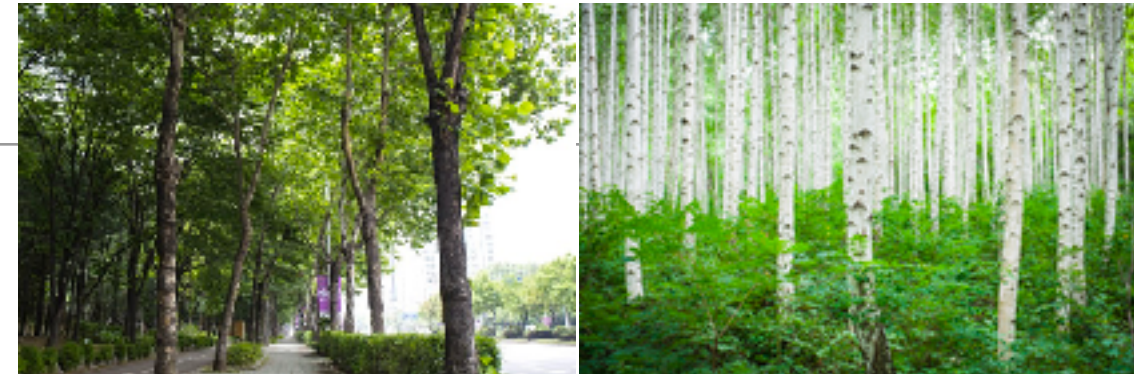
Introduction to Green Roofs

Brought to you by **Greensulate**

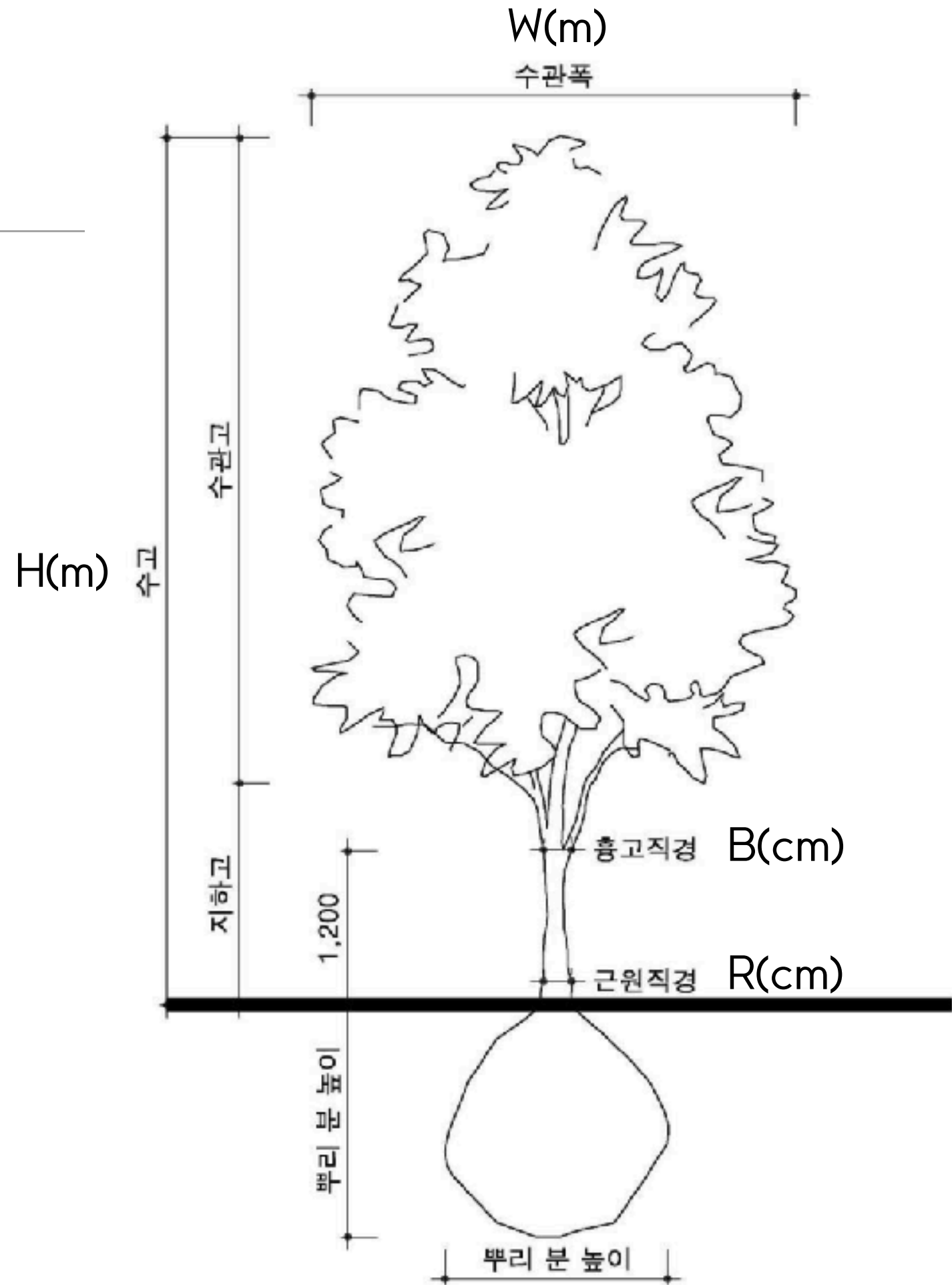


수목의 구분

| 구분 | 비고 |
|-------------------|--|
| 관목 灌木 shrub | <p>영어로 번역할 때 '덤불(bush, shrub)' 이라고 불리는 키가 작은 나무들입니다. 주로 사람 키보다 작게 자라고 땅에서부터 여러갈래의 목질의 줄기가 자라나는 나무를 말합니다. 밑동이나 땅속부분에서 여러가지의 가지가 갈라져서 나오기 때문에 일반적으로 교목보다 수고가 낮고 곧은 뿌리가 없으며 수형이 일정치 않습니다. 줄기의 수명이 비교적 짧고 죽은 줄기 밑동에서 새로운 줄기가 나오는 경우가 많습니다. 개나리, 진달래, 라일락 등의 꽃나무가 여기에 속합니다.</p> |
| 교목 喬木 arbor | <p>일반적인 개념의 '나무(tree)'가 여기에 속해요. 영어로 번역 시에 tree가 되는데, 일반적으로 큰키나무, 즉 높고 크게 자라는 나무를 뜻합니다. 주로 다년생 목질의 굵은 줄기가 있고 이 굵은 줄기에서 갈래로 가지가 퍼져나가는 나무들을 일컫습니다. 우리가 길에서 흔히 보는 사람키보다 큰 커다란 나무들이 교목에 속합니다.</p> <p>주로 땅에서 나오는 줄기가 하나로 시작되는 나무를 일컫고 나이트가 있는 두꺼운 나무기둥을 가진 나무들입니다. 크기에 대한 정의는 정의를 내린 곳마다 다양하지만 일반적으로 8m 이상 크게 자라고 윗부분이 잎으로 덮인 나무들을 말합니다. 가로수로 흔히 볼 수 있는 플라타너스, 단풍나무, 사과나무, 은행나무 등이 모두 교목에 속합니다.</p> |



수목의 명칭



Course Objectives

Understand how green roofs work and why they are

- beneficial to both the indoor and outdoor environment
- Differentiate the type of green roofs and their respective benefits
- See how green roofs have been successful in real life case studies
- Know what to look for in a green roof installer

Course Overview

- Green Roof History
- What Is a Green Roof?
- Types of Green Roofs & Systems
- Green Roof Benefits
- Green Roofs & LEED
- Government Incentives
- The Importance of Green Roof Maintenance
- Green Walls and Facades
- Examples and Case Studies
- What to Look for in a Green Roof Installer

Green Roofs

Used for 1000s of years

- Cool buildings in Africa
- Retain heat for Vikings



Green Roof History

Pre -Modern History

- Scandinavia, Iceland: sod and turf insulated homes.

History: 1914, Moos Water Filtration Plant, Zurich

- Oldest recorded green roof structure.
- Nine acre roof meadow on water treatment center.
- Installed for temperature moderation of building.
- Roof membrane has remained intact, only requiring reconstruction around edging.

Today: Industry Growth in a Recession

- Estimated 3.1 million ft² installed in 2008.
- Estimated 10 million ft² installed in 2009.
- From 2007 to 2009 the market increased by 35%.
- In 2009, the green roof industry grew by 16%.
- In 2010, the green roof industry grew by 28.5%.
- In 2011, the green roof industry grew by 115%.
- In 2012, the green roof industry grew by 24%.



What Is a Green Roof?

A layered, living extension of the roof construction

A natural, efficient, time- tested insulation method

Extensive 저관리형 경량형

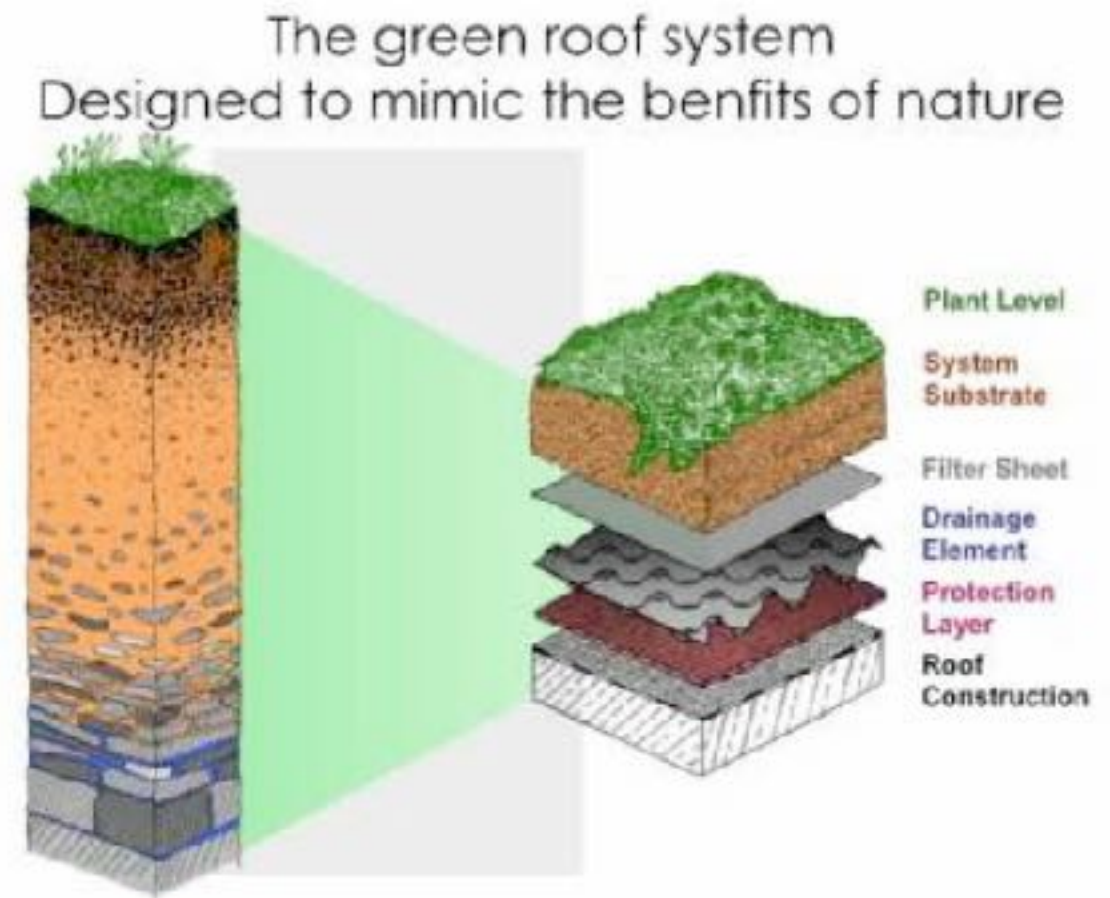
- green roofs are low-lying, under-six inch performance-driven systems that meet engineering and insulation goals

Intensive 관리, 중량형

- green roofs are higher- profile, over-6 inch systems designed for functional & aesthetic goals in addition to core performance needs

Hybrid

- Systems employ facets of both



Types

Intensive

- Like a garden

Extensive

- Slow Growing, Stress-tolerant plants

Semi-Intensive

- In-between



대도시의 경우 생활권 공원면적 $1\text{m}^2/\text{1인}$ 확보를 위해서 천문학적 비용이 소요된다.

이처럼 지상에서 불가능한 녹지량을 확보할 수 있는 유일한 대안이 옥상이다.

건축물의 옥상을 정원화함으로써 얻어지는 효과로는

- 건축물의 가치상승,
- 지상의무 조경면적을 대체,
- 에너지 비용의 절감
- 건축물의 보호효과 등 이 있다.

Types of Green Roofs

Extensive green roof

- low maintenance
- no irrigation
- from moss-sedum to grass-herb green roofs
- build-up height 2.4 – 6 in.
- weight 10 – 30 lb/ft²
- retention .5–1.5 gal/ft²

Plants replace gravel on the roof

Semi-intensive green roof (Hybrid)

- periodic maintenance
- periodic irrigation
- from grass-herb roofs to green roofs with shrubs
- build-up height 4.7 – 10 in.
- weight 30 – 40 lb/ft²
- retention 1– 2.5 gal/ft²

Designed for green roofs with higher demands

Intensive green roof

- regular maintenance
- regular irrigation
- from lawn or perennials to shrubs and trees
- build-up height 6 – 20 in.
- weight 30 – 100 lb/ft²
- retention 2–5 gal/ft²

Well-maintained gardens on utilized, flat roofs

Types of Green Roofs : Benefits

Extensive green roof

- Lightweight
- Suitable for larger areas
- Low maintenance costs and can be designed for no irrigation
- More suitable for retrofit projects
- Low Cost
- Easy to replace



Semi-intensive green roof (Hybrid)

- Combines best features of Intensive and Extensive
- Maximizes design and plant choice over areas with greatest load capacity
- Greater coverage at relatively low cost
- Average amount of maintenance
- Greater plant diversity
- Creates opportunities for design



Intensive green roof

- Largest plant diversity
- Best insulation properties and
- storm water management
- Greatest range of design
- Usually accessible
- Greater variety of use



옥상정원의 유형별 식재수종 및 녹화 방식 등의 비교

| 구 분 | 저관리 경량형 | 관리 중량 |
|--------|-----------|----------------|
| 식재수목 | 소관목, 지피식물 | 아교목, 관목, 지피식물 |
| 토심깊이 | 2-12cm | 20cm 이상(60-90) |
| 대상건물 | 신축, 기존건물 | 신축건물 |
| 토양의 하중 | 경량(인공경량토) | 중량(일반토양) |
| 녹화방식 | 전면녹화 | 부분녹화 |
| 유지관리 | 관리요구 최소화 | 관수, 시비관리 필요 |

유형별 설치기준

옥상정원의 유형은 일반적으로 허용하중

- 저관리 경량형 200 kgf/m^2 이상
- 혼합형 300 kgf/m^2 이상,
- 관리 중량형 400 kgf/m^2 이상

이 허용하중을 기준으로 식생의 종류와 녹화 시스템을 구성하여 설치하여야 한다.

저관리 경량형

- 이용개념이 배재된 유형
- 최소 관리로 최초 식재한 식물이 이입종에 영향을 받지 않고 10-15년 지속
- 낮은 토심(2-12cm), 경량형(100kg/m² 내외)
- 지피식물 위주 식재
- 자생 세덤류(돌나물, 땅채송화, 애기기린초 등), 외래세덤류 등

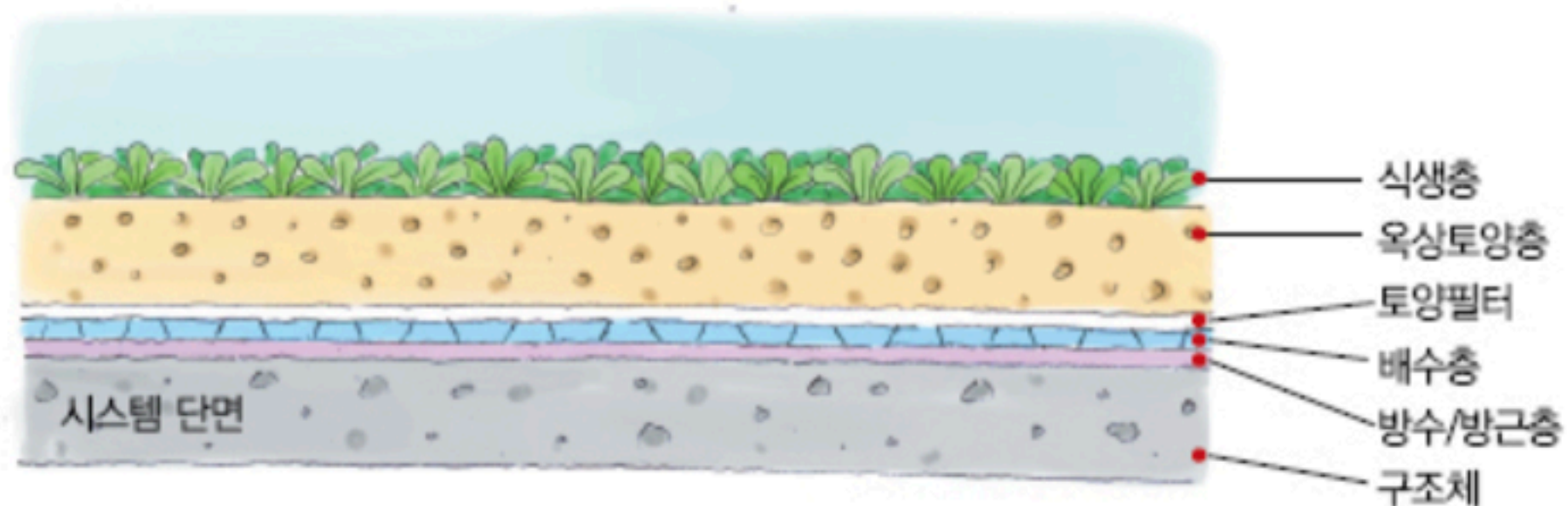


그림 1. 저관리 경량형 옥상정원 구조

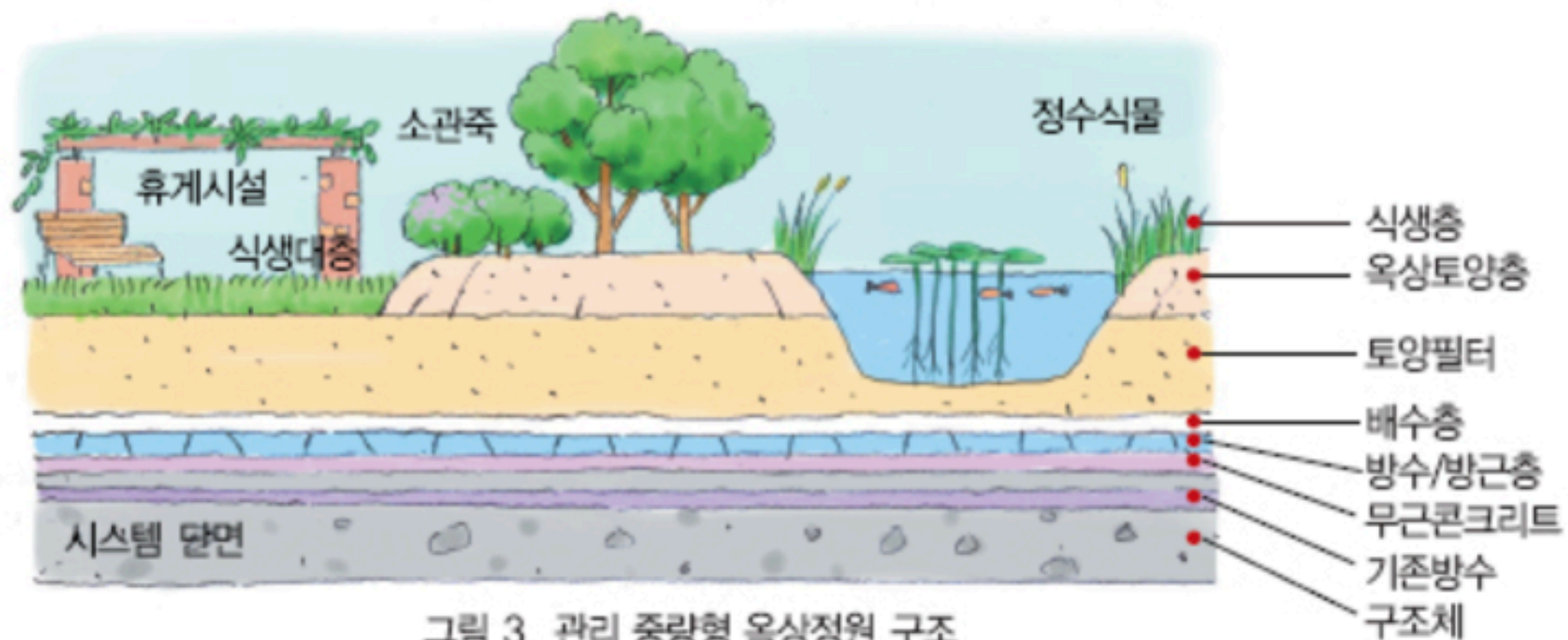
혼합형

- 경량형과 중량형 혼합
- 이용개념 적용가능
- 관리 필요
- 낮은 토심(10-20cm) 부분적 마운딩
- 지피, 관목류 식재
- 기존 건축물에 이용 개념을 도입한 옥상녹화를 원할 때에 적용이 가능한 유형이다.



관리 중량형

- 이용을 전제로 하는 녹화시스템
- 관수, 시비, 예초, 전정 등 관리가 요구됨
- 토심 20cm 이상
- 지피, 관목, 아교목 식재
- 구조적 안전성이 충분한 신축건물에 적용이 가능한 유형이다.



옥상정원의 구성요소

- 옥상정원은 건축물의 외피인 옥상이나 지붕을 식물이 살아갈 수 있는 공간으로 구성하는 작업이라고 할 수 있다.
- 옥상정원은 파괴된 자연지반과 이에 수반되는 자연생태계를 복원하기 위해 건물옥상에 생물 서식 기반을 제공하고 원예적인 활용을 유도하는 것이다.
- 옥상정원의 설치를 결정할 때에는 적용대상 건물이 기존 구조인지 신축 구조물인지 먼저 고려하여야 한다.
- 기존 건축물인 경우는 가능한 허용 적재하중 범위 내에서 시스템의 적용이 이루어져야 하며 신축건 물은 사전에 설계에 반영하여야 한다.
- 기존 구조물의 경우 설계된 허용중량이 얼마인지 먼저 파악하고 반드시 현장에서 구조안전진단을 통해 설치 가능여부를 판단하고 필요시에는 구조를 보강해야 한다.
- 기 존 방수에 문제가 있는 경우에도 적합한 방수층을 새로 시공한 후 설치해야 한다.

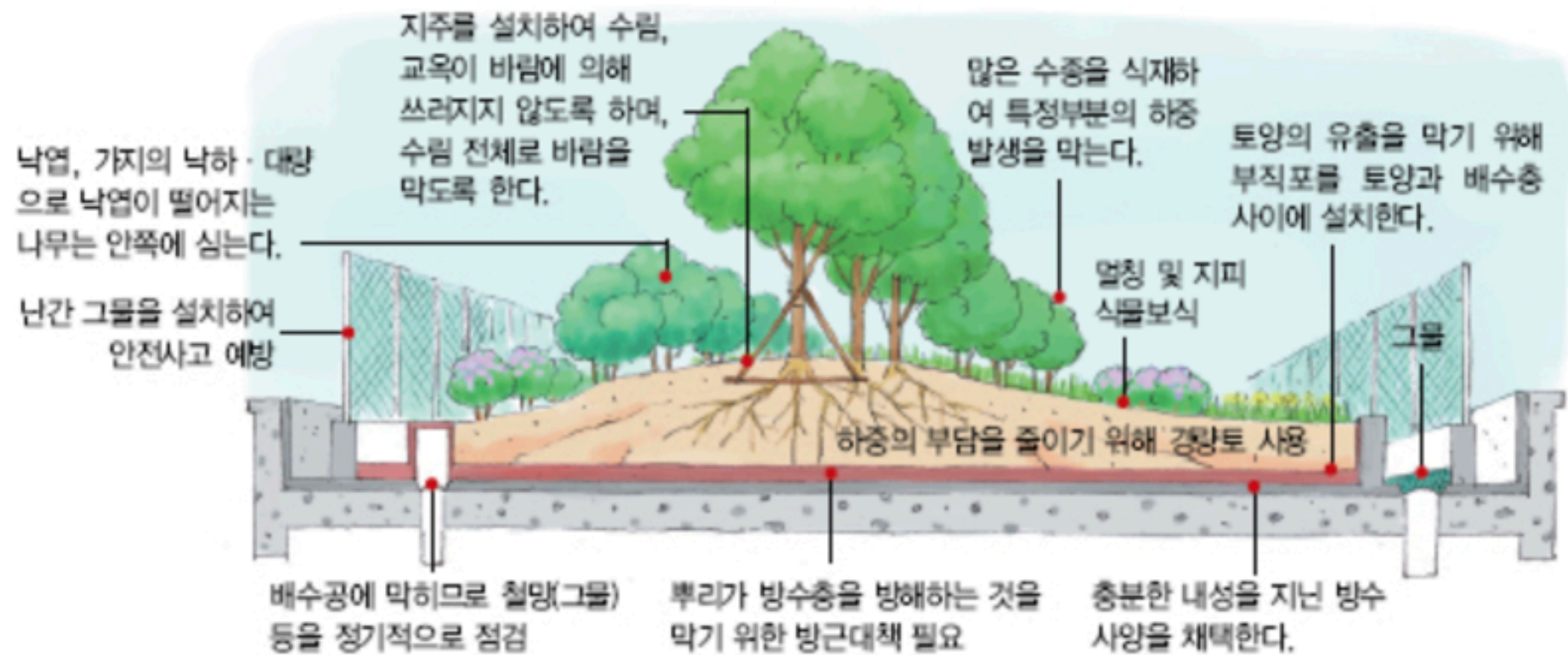


그림 4. 옥상녹화시 고려해야할 물리적 측면

옥상정원의 유형별 식재수종 및 녹화 방식 등의 비교

| 구 분 | 구성요소 | 기능 및 내용 |
|-------|--------|---|
| 건축물외피 | 구조안전진단 | <ul style="list-style-type: none"> · 옥상정원 시스템을 지지하는 구조전체 검토 · 설계시 허용하중 및 구조적 보강가능성 등 검토 |
| | 방수진단 | <ul style="list-style-type: none"> · 옥상정원 시스템으로 인한 건물 누수차단 역할 · 옥상정원 시스템의 내구성에 가장 영향을 주는 부분임 |
| 식재기반 | 방 근 층 | <ul style="list-style-type: none"> · 식물의 뿌리로부터 방수층과 건물을 보호 · 시공시 기계적, 물리적 충격으로부터 방수층을 보호하는 역 |
| | 배 수 층 | <ul style="list-style-type: none"> · 옥상정원시스템이 침수되어 식물의 뿌리가 죽은 것을 예방 · 하자발생이 가장 많은 부분이므로 신중하게 설계해야함. |
| | 여 과 층 | 토양이 빗물에 씻겨내려 하부로 유출되지 않도록 여과하는 기능 |
| | 토 양 층 | <ul style="list-style-type: none"> · 식물이 지속적으로 생장하는 기반 · 옥상정원시스템 중량의 대부분을 차지하므로 경량화 노력 |
| 식생층 | 식 생 층 | <ul style="list-style-type: none"> · 옥상정원 시스템의 최 상부 구성요소 · 유지관리를 위한 토양층의 깊이, 토양의 특성 고려 필요 |

Intensive (6"+)

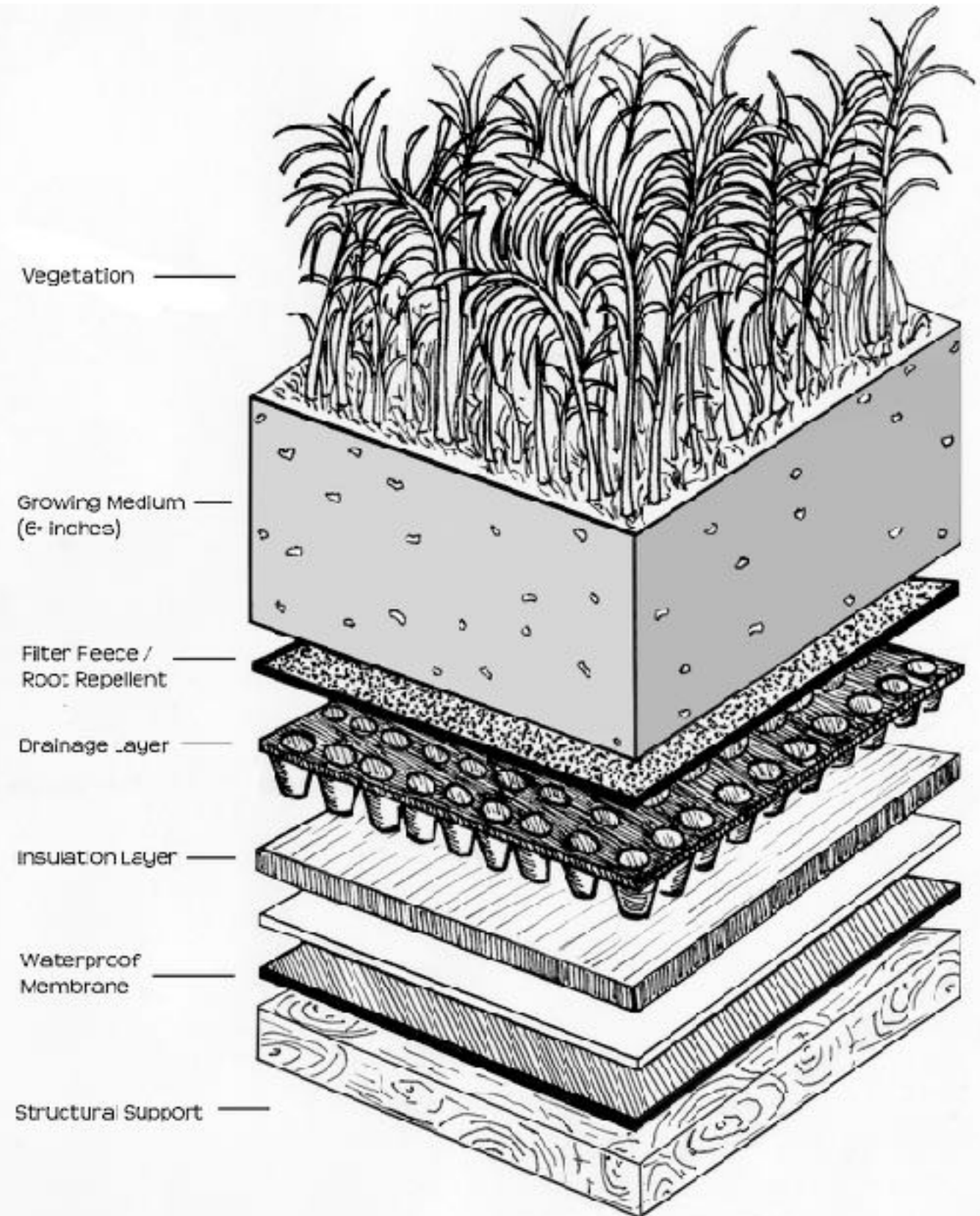
150+ mm layer
substrate

Plants, vegetables,
shrubs, trees,...

Frequent
maintenance needed

Heavy

Provide a “park”
where land is too
expensive



www.greenroofplan.com

Intensive

Baltimore Convention Center



Intensive

Yale University
Smilow Cancer Hospital

Extensive ($\leq 4''$)

Sedum Roof

- 20–100 mm substrate
 - cuttings or plugs, or pre-grown mats

Meadow Roof

- 70–100 mm substrate
- Dry habitat wildflower & grass seed mixes

Brown or Biodiversity Roofs

- Allow a natural habitat to develop
- Use crushed brick, leftover soils for substrate

Pre-Vegetated Mats



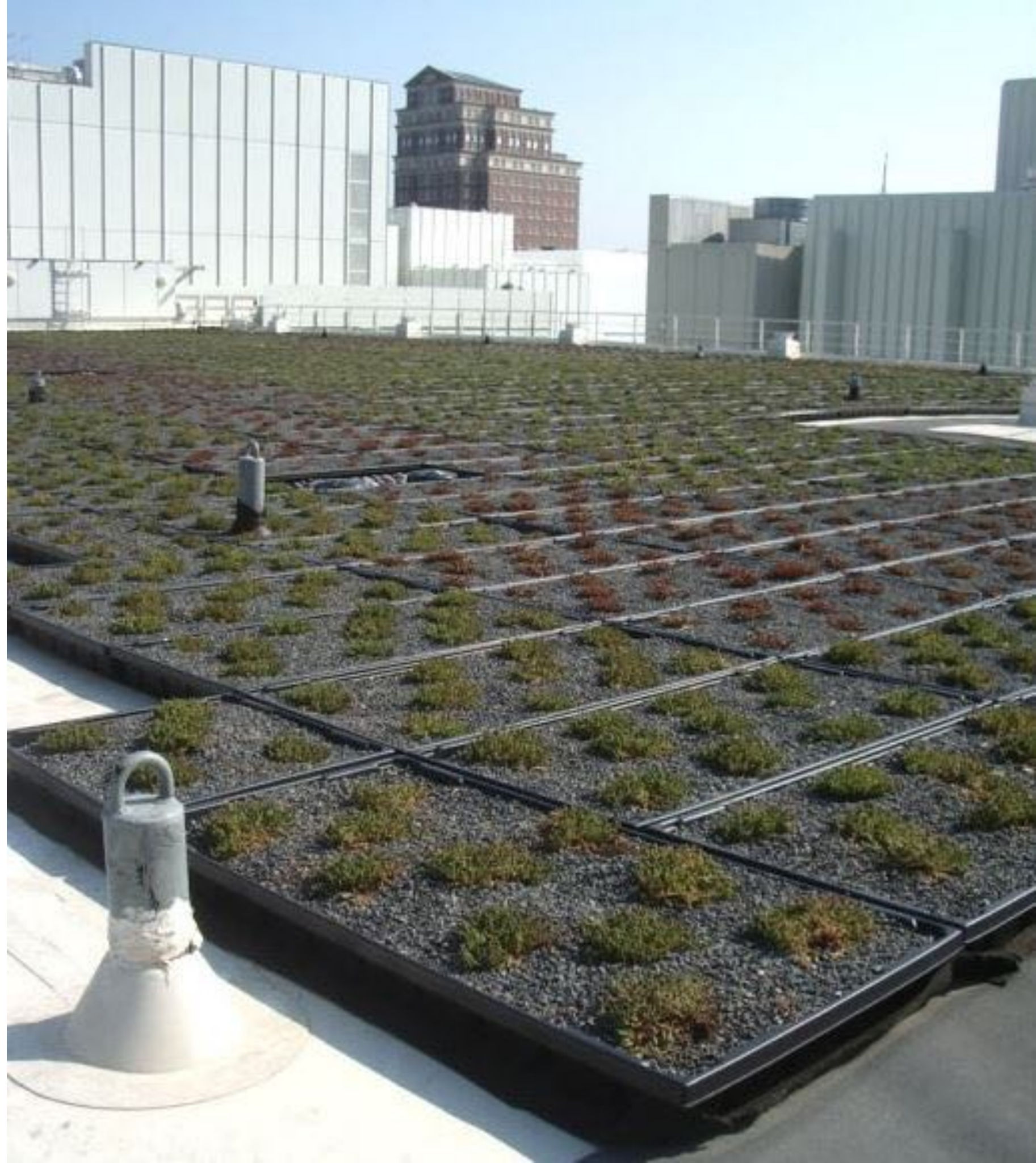
**Xero Flor
Pre-Vegetated Mat**

**XeroTerr
Growing Medium**

**XF157
Water Retention Fleece**

**XF108H
Drain Mat**

**XF112
Root Barrier**



Sedum



Water Treatment Facility, New Haven, CT

30,000 ft² green roof was largest in Connecticut in 2010



Modular Trays - Sedum

Sedum



J.W. Winco (New Berlin, WI) 15,800 ft² green roof

Captures >18,000 gallons during 1-inch rainfall event

Reduces heating and cooling, improves air quality, extends roof life

Augustenborg Botanical Roof Garden, Malmö, Sweden



Home, California



©Saxon Holt / PhotoBotanica

Brown

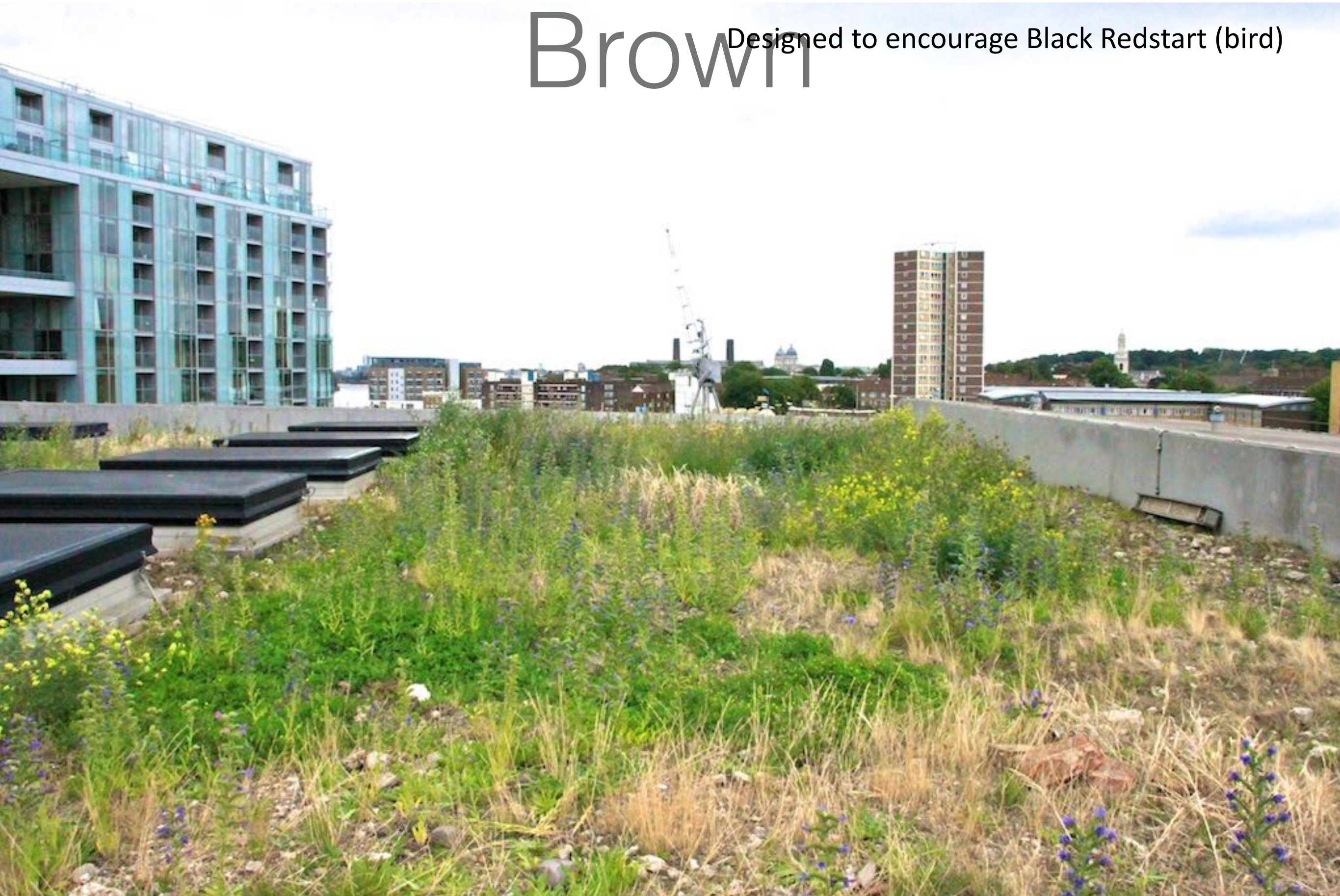


Lambeth, Central London, UK
Brown rubble substrate

Laban Dance Center, London England

Brown

Designed to encourage Black Redstart (bird)



Semi-Intensive

At least 25 % (roof area) of substrate
above (or below) 6"

100 – 250 mm substrate

- Greater diversity of plants, compared to extensive
- Still focused on
 - low maintenance plants
 - Lower weight

Semi-Intensive

Germany



Semi-Intensive

Chicago City Hall (2001)



www.greenroofs.com

Types of Systems

Built-Up/"Built in Place":

- Comprised of single-ply roofing membrane layered with a plastic drainage material, filter fabric, and moisture retention mat under the vegetation.
- Loose laid growing medium; followed by the planting of vegetative plugs, clippings or pre-grown mats.
- On average, costs \$8 to \$9/ft² less than a modular system.

Modular/Tray:

- Typically pre-grown vegetated panels (often 1' wide by 2' long, with 4" depth) with growing medium and plants contained.
 - Trays often connect to create a monolithic look which is mature at installation.
 - Simple installation: requires a crane for lifting and easy arrangement of trays.
 - Maintenance: if the black roof leaks, trays can be moved quickly.
- Additional Roofing Elements:
 - Lighting, decking, beehives, solar panels, data monitors, rain barrels, as well as recreational areas may be included in design.

Green Roof Benefits

Increase life of roof membranes

- Reduce UV & Mechanical damage
- 2 – 3 times greater life span
 - Roof can last building life time

Energy savings

- Can reduce air conditioning needs by up to 75 %
 - Better Insulated
 - Evapotranspiration cooling

Benefits

Reduce storm water

- Less costly than traditional systems

Reduce urban heat island effect

Meet green building standards

Meet planning requirements

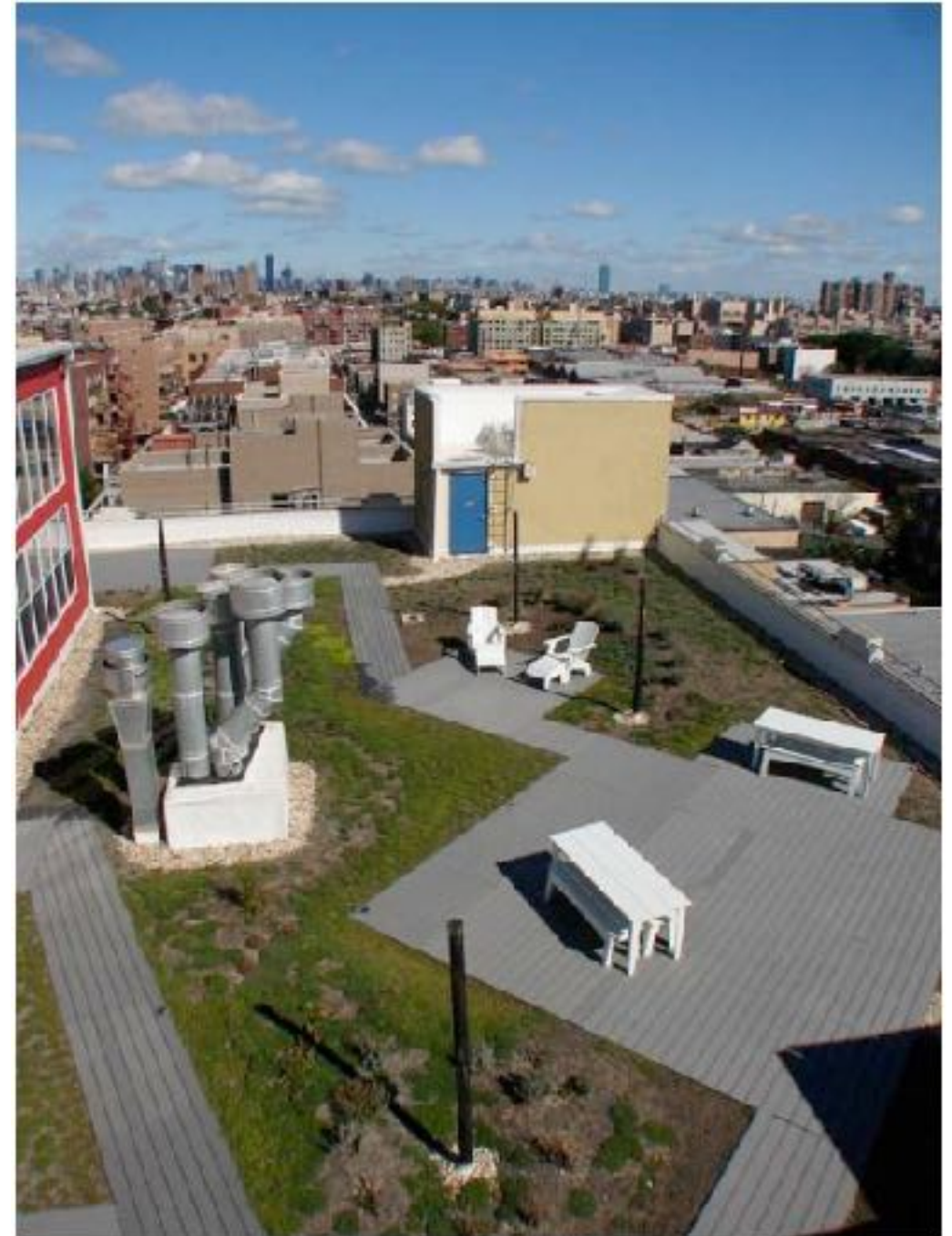
Some construction wastes can be incorporated into substrate

Increase property value

Green Roof Benefits:

Public

- Stormwater quantity, quality, and flow reduction
- Biomimicry/biodiversity
- Reduction in urban heat island effect
- Improved air quality
- Waste diversion: less refuse from repairing asphalt/black roofs
- Local job creation
- Aesthetics



Stormwater Management

Reduce Volume: Cities use green roofs to effectively reduce volume of stormwater runoff:

- Green roof soil and vegetation reduces runoff rate by absorption and evapotranspiration.
- Green roofs hold rainwater, delaying flow to sewer systems.
- 50 to 90% of the rain is retained on an extensive green roof.
- New York City townhouse study: during a 1" rainfall 100% water retention was achieved.
- City of Portland study cited a 96% reduction in peak flow (rate of movement).

Improved Quality:

- Green roofs improve stormwater runoff quality, filtering out 95% of cadmium, copper, and lead, and 30% of the nitrogen and phosphorous in storm water.

More Effective:

- Grey infrastructure (piping, tanks, engineering solutions) is costly and ineffective

“Over 400 river outlets dump **27 billion gallons of untreated overflow** into its harbor each year, according to Riverkeeper, a local advocacy group.”

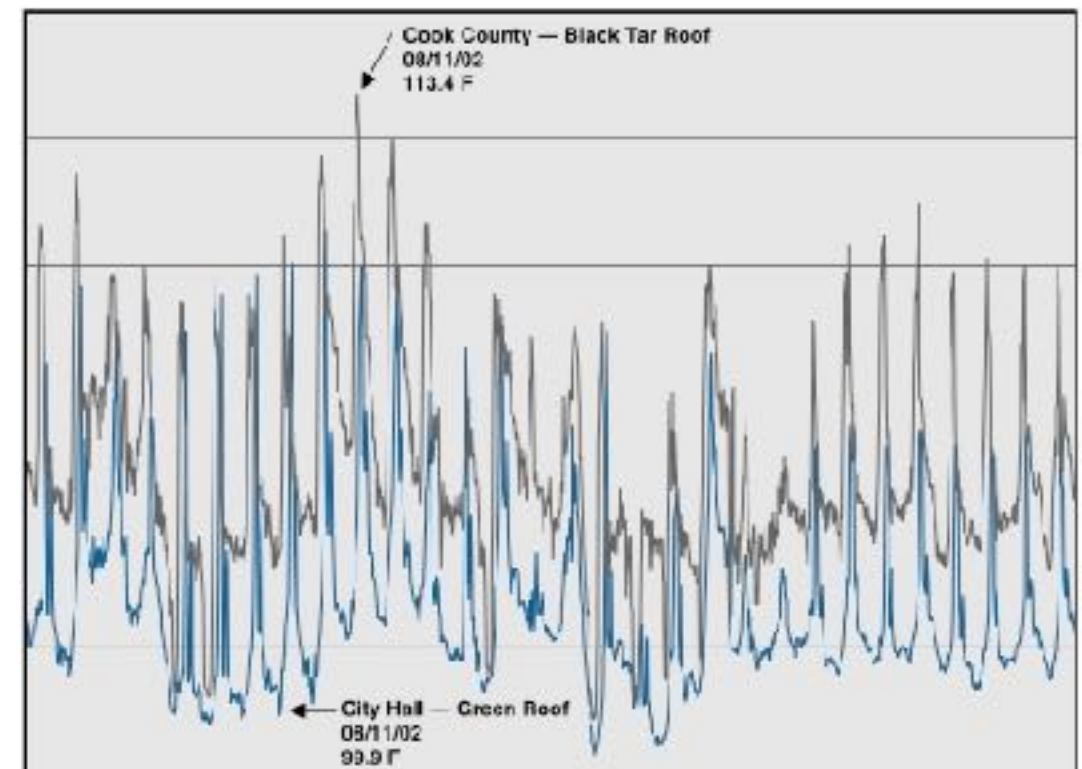
-The Economist, 11/11/10

Urban Heat Island Effect

- Urban Heat Island Effect: greater ambient temperature in cities over surrounding areas, caused by increase in development which uses impervious materials. One effect is the decrease of open land and vegetation.
- The U.S. Environmental Protection Agency estimated that urban heat exposure killed more Americans between 1979 and 2003 than did hurricanes, lightening, tornadoes, floods, and earthquakes combined.
- On average, the difference between a city with over one million people can be from 9° F to 27° F higher than surrounding rural areas.

- Comparative Analysis – Green Roof vs. Black Roof - August 2002
Temperature difference of City Hall in Chicago in August '01
 - City Hall paved roof surfaces 91° -119°
 - City Hall green roof surface 126° -130°
 - Cook County black tar roof 169

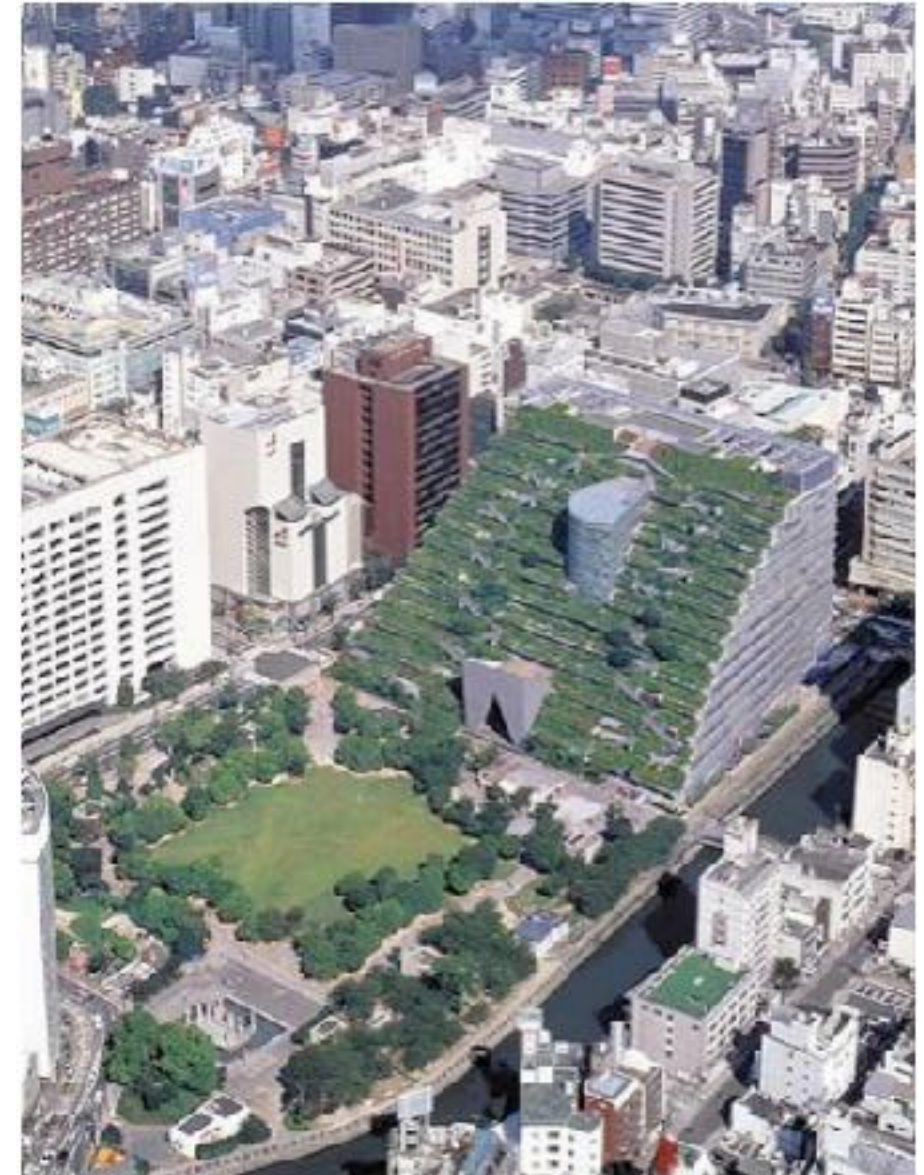
Federal Energy Management Program, Federal Technology Alert, “*Green Roofs*,”
U.S. Department of Energy, Energy Efficiency and Renewable Energy, 2004.



Air Quality Improvement

Green roofs filter particulate matter from the air & absorb greenhouse gases.

- N₂O (nitrogen oxides), produced by automobile traffic, are a major cause of human respiratory disease.
- CO₂ sequestration: mitigates global warming.
- A 1000 sq. ft. green roof eliminates approximately 40 pounds of particulate matter each year, the equivalent of 15 cars/yr¹



ACROS Fukuoka Prefectural International Hall was created in 1994 to recreate a mountain-like atmosphere in Fukuoka Japan.

Local Job Creation

Design and Engineering:

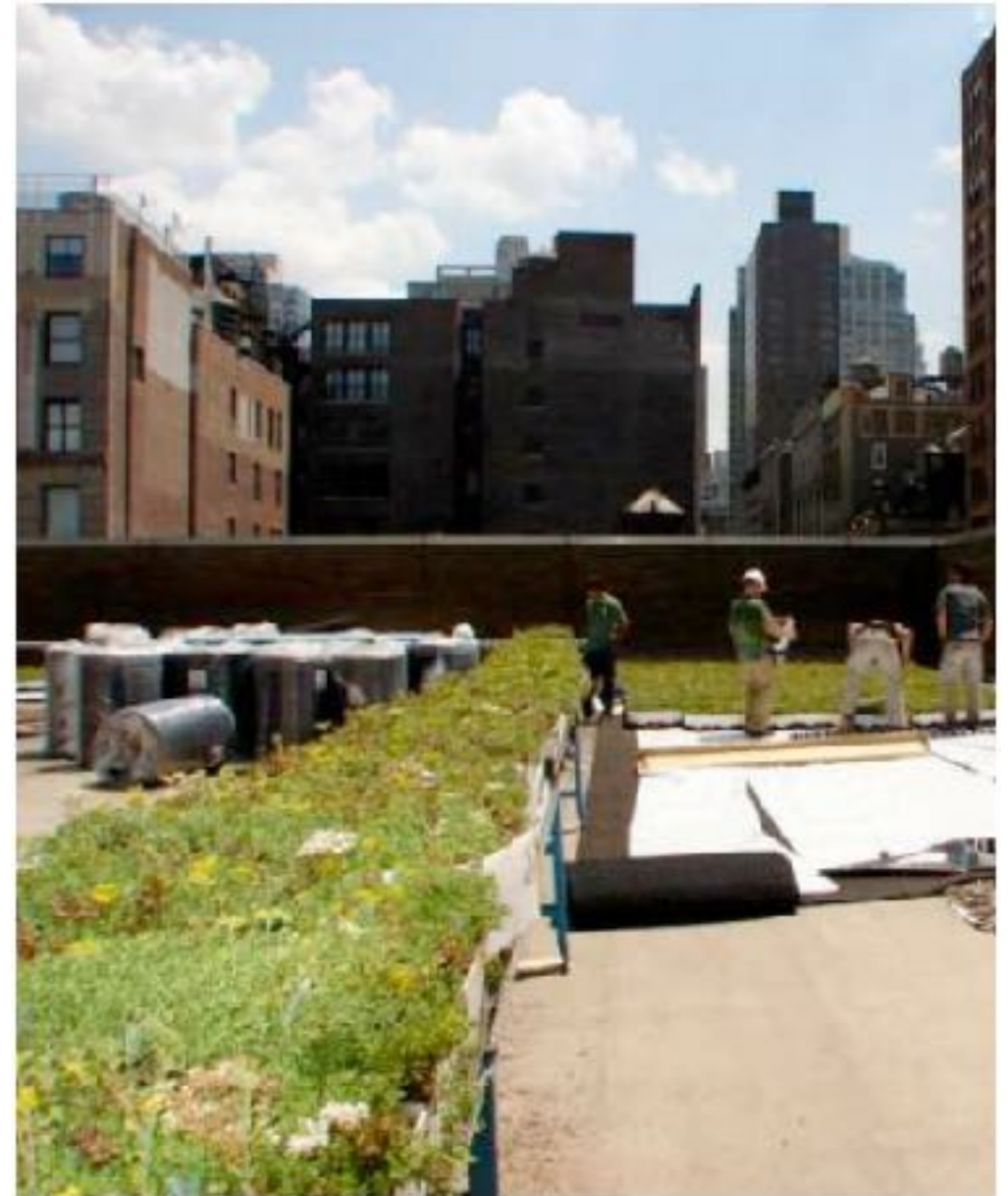
- – Greensulate partners with local architects, engineers.

Installation:

- Site will be managed by Certified GRPs from Greensulate, hiring as many local installers as possible.

Maintenance:

- Greensulate will qualify and train a local partner.
- Greensulate will oversee quality control and include a plant warranty.



Greensulate team during the Green Roof installation at New York City's Fashion Institute of Technology.

Urban Heat Island Effect

- Significant Annual Energy Cost savings •
- Adds a minimum insulation value of R-7 •
- More effective and cleaner HVAC
- 13 potential LEED points
- Roof membrane life increases by 2 to 3 times
- Tax Incentives, abatement stimuli and rebates
- Noise Reduction
- Increased Property Value
- Increased Workplace Productivity •
- Aesthetics



Greensulate intensive rooftop garden on Convent Avenue in Harlem, New York.

Energy Efficiency

Columbia University, CUNY & Con Edison Green Roof Energy Efficiency Study¹

Dr. Stuart Gaffin, The Earth Institute at Columbia University:

- Climate Systems Researcher involved in green roof movement.
- Measuring the quantity and quality of the water runoff from the green roof on Regis High School project (Excess storm water runoff in urban areas leads to combined- sewage-overflows that pollute waterways).

Insulation, Energy Savings:

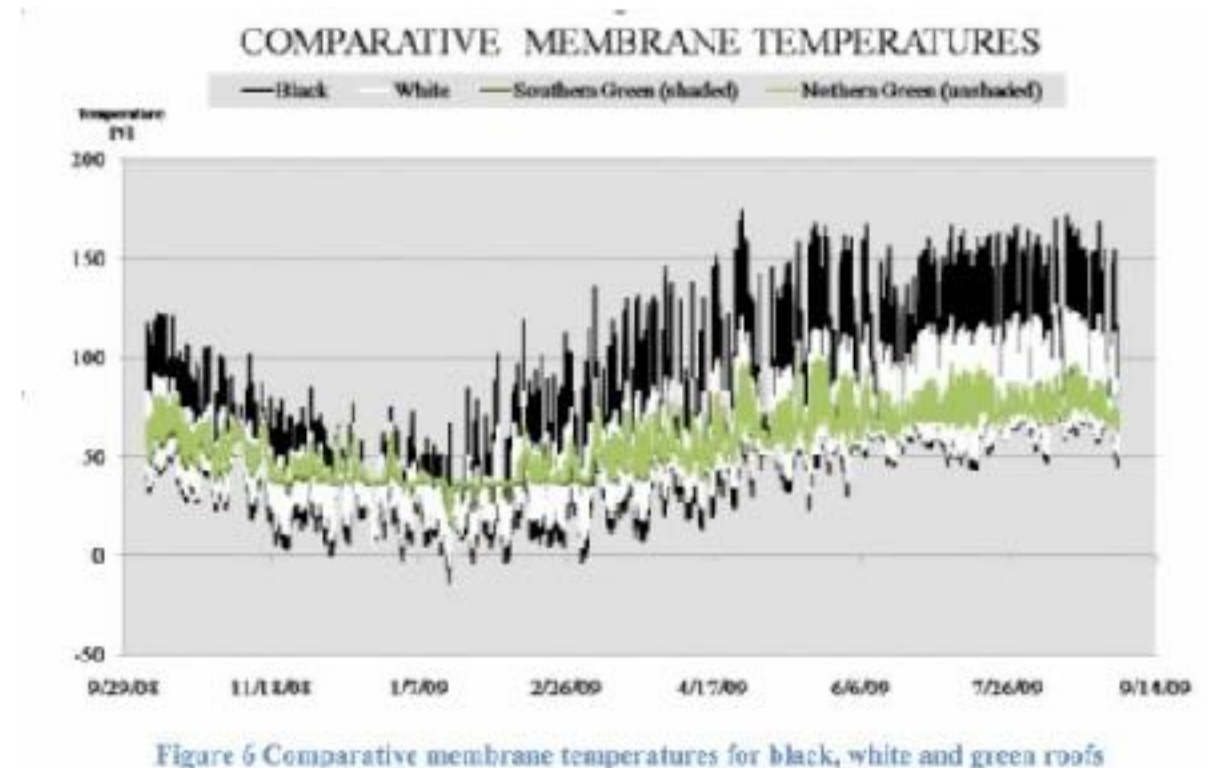
- 87 % reduction in heat gain from green roof in summer.

- 37% percent reduction in heat loss during winter.
Peak Temp on Hottest Day:

- Tar Roof: 176°F

- White Roof: 146°F

- Green Roof: 116°F
Building Details: 10,764 sq.ft. green roof with
21,000 plants. ¹ April 2010



Energy Savings

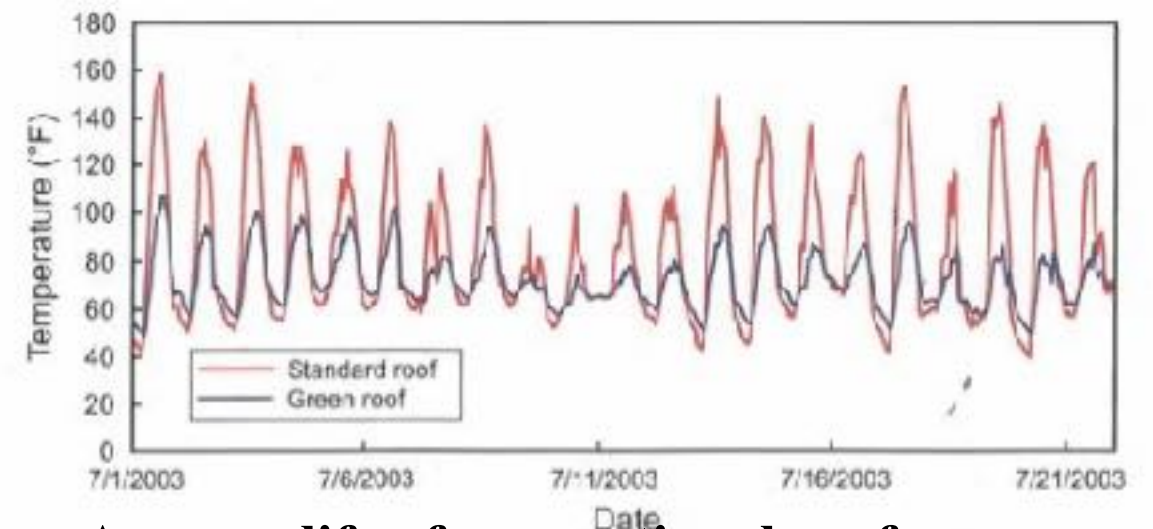
Building Energy Savings Simulation: Department of Mechanical and Materials Engineering, Portland State University, (David Sailor, February 2008)

- Building Details
 - – Two-story office buildings, each totaling 43,055 ft², in Chicago.
 - – 4000 ft² green roof, intensive green roof.
- Energy-Plus Method, developed by US Department of Energy:
 - Method used to identify energy savings depends upon changes in plants, soil temperature.
- Electricity Savings
 - 2% average annual savings.
- Natural Gas Savings
 - 9% average annual savings.
- Energy use
 - Dormant plant biomass and growing medium is effective throughout winter.

Extension of Roof Life

Conventional Waterproof Membranes degrade over time due to:

- Expansion and contraction from temperature fluctuations.
 - UV exposure.
- Using a 40 year Lifecycle Cost Analysis, green roofs cost less than conventional roofs¹. Green Roofs last twice as long while also saving energy and reducing overall operating costs.



Average life of conventional roof = 15-20 years.

Average life of green roof = 40 years.

Raise Property Value

“ Green Roof Installation Raises Value of Boston Apartment by \$2.4 Million ”
(Tim Blackwell, December 28, 2012)

- Green Roof installation cost \$112, 500
- Generating an additional \$300 to \$500 per month in revenue for the 25 units that overlook the roof
- Property expects to generate about \$120,000 in additional revenue annually
- At 5% cap rate, J.P Morgan Asset Management estimate the green roof has improved their value of the property by \$2.4 million



Improves Solar Panel Performance

Solar Energy Efficiency Improvement

- – Studies show that solar panel efficiency improves by as much as 25% when combined with a green roof.
- – Green roof cools the ambient air temperature and offsets the warming around the panels.
-

Installation

- – Panels can have a shade tolerant sedum planted underneath, in which the panels provide the cool shade.
- – An 18” clearance from panels to roof is ideal.
- – Shade from panels reduces the amount of watering needed.



The Importance of Green Roof Maintenance

- Establishment Period
 - Installation ideally before first frost or after last. Roof is established at 80% coverage.
 - First 2 to 3 years critical to long term success.
 - Water Availability
 - Initial watering is required in first few weeks of installation.
 - Plants do not require long term irrigation, they can be weaned off and adjust to the local climate.
 - Weeding
 - Pre-grown modular systems incur less weed pressure due to plant density.
 - Woody tree seedlings, interlopers should be removed.
- Nutrient Testing
 - Growing media requires specific levels of nutrients, and pH levels in water.

Cost Factors

Type of green roof

Extra support structure (Intensive)

Engineering fees

Pitch, edging and roof details

- guttering, skylights,...

Roof Size

- economy of scale

Time of year and type of planting

Building height – Crane

Maintenance, irrigation and access

Cost

As much as 2x cost of waterproofing & insulating standard roof



Maintenance

Annual removal of unwanted weeds & saplings

Annual clearing of drainage outlets

- Same as traditional roofs

Irrigation in case of drought

Best to pay installer maintain for ~2 years, until plants established

Structural Support

Extensive green roofs fall within load of standard roofs

| Type | Load per area (kg/m ²) |
|----------------------|------------------------------------|
| Gravel Surface | 90 - 150 |
| Paving Slabs | 160 - 220 |
| Extensive green roof | 60 - 150 |
| Intensive green roof | 200 - 500 |

Pitch

Any pitch is possible

- Above 9.5° care must be take to keep substrate in place and retain water
- Cross battens can be used up to 35°
 - Closer together as pitch increases



Components

Vegetation

Substrate

Drainage /
Aeration / Water
Storage / Root
Barrier

Insulation

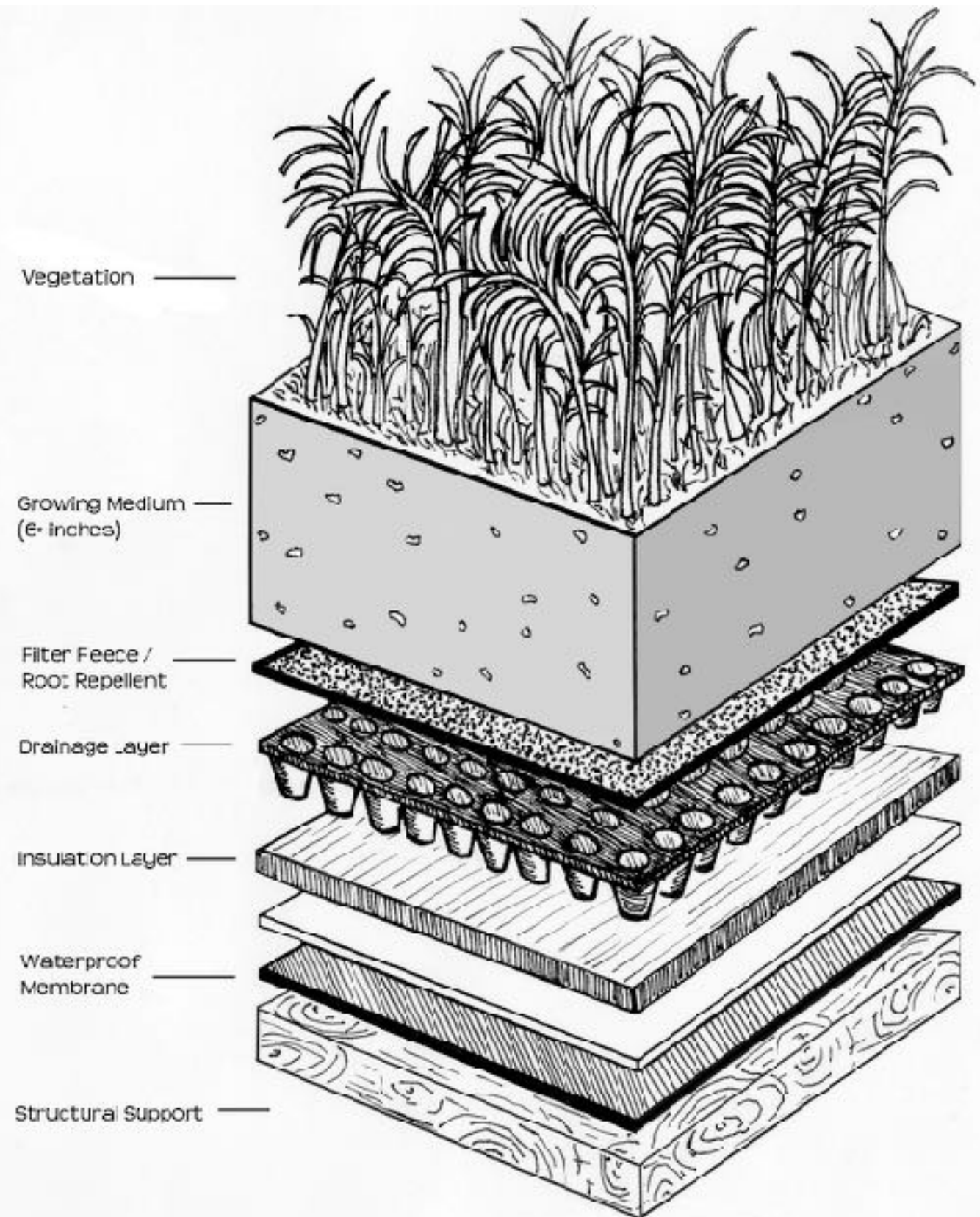
Membrane
Protection &
Root Barrier

Roofing

Membrane

Structural

Support



www.greenroofplan.com

Planting Options

Pre-grown Mats

- Cover established fast, highest cost, low diversity

Plugs

- Lower cost, cover takes a bit longer, some plants may not be available

Seeds or cuttings

- Low cost, 1-3 years to establish, sow in fall/spring

Natural Colonization

- Lowest cost, high biodiversity, aesthetics may suffer, longest time to establish

Installation

Modular

- Trays

Layers



Trays

ESRI Canada – Garden in the Sky

Trays!



Layers





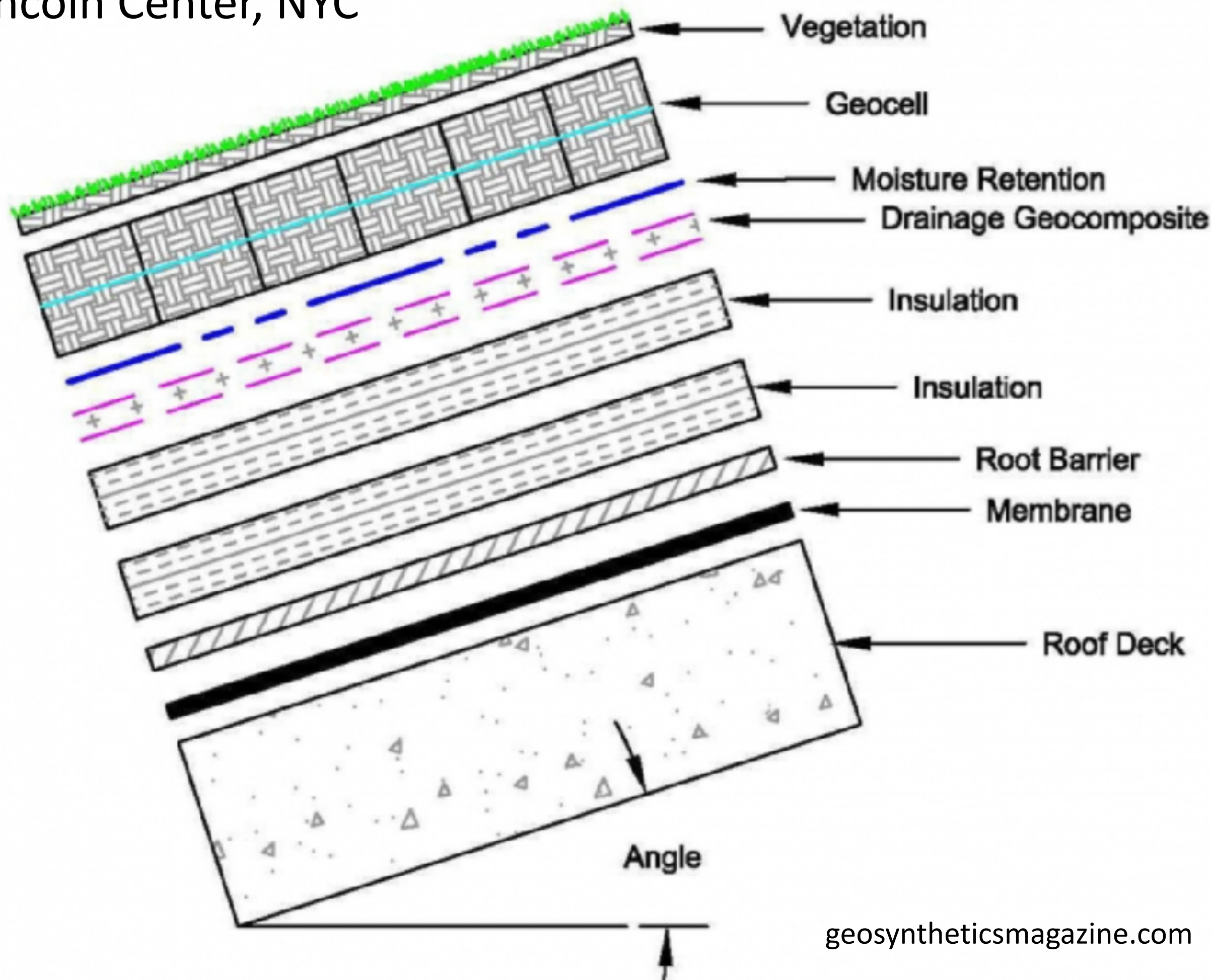
Lincoln Center, NYC

geosyntheticsmagazine.com

Geocells

geosyntheticsmagazine.com

Lincoln Center, NYC



Government Incentives

Tax abatements and incentives tied to green roof installation are available in many cities, nationwide.

- Future of Green Legislation: Portland / NY / CHICAGO
 - Many governments are writing policies which will require property owners to implement systems that mimic pre-development hydrology.
 - Building owners will be required to audit and report energy efficiency.
 - Government will assess and tax buildings based on non-permeable footprint. Alternatively, they will incentivize building owners, likely through tax abatements and credits, to “green” non-permeable spaces.
 - For example, in Portland, Oregon, all new municipal buildings are required to be designed and constructed with a green roof that covers at least 70% of the roof.
- New York City:
 - September 2010: Bloomberg Administration announced plans to invest \$1.5B in storm water management and cited green roofs as a solution.
 - Annual DEP Storm-Water Management grant, awarding up to \$6mil in 2013.
 - Tax Abatement currently \$5.23 per ft² with a cap of \$200,000. Broad group of cross-industry professionals working to raise this abatement. SWIM Coalition.

Green Walls and Facades

Modular Panel Systems

- ◆ May be flushed to wall or as far as 18" from wall
- ◆ Protects building surfaces
- ◆ Rigid 3-D panels/screens designed in curves, flat, or circular designs
- ◆ Can be freestanding as security/privacy fences
- ◆ Made of recycled metal

Highly customized

Wire-Rope & Cable Net Systems

- ◆ More affordable than modular systems
- ◆ Single rope features terminated wires secured to wall in 4 places
- ◆ Cable systems with stainless steel wires include cross clamps with columns
- ◆ Onsite assembly

Flexible, natural design

Living Walls

- ◆ Interior or exterior options
- ◆ Manufactured off-site
- ◆ Cast in wood, concrete, or metal frames
- ◆ Hydroponic irrigation
- ◆ High maintenance
- ◆ Can be integrated into ventilation and HVAC systems

Waterproofing and gutter systems recommended

Examples of Green Walls



Modular Panel System



Trellis System



Living Wall with Irrigation

Case Studies: Green Roof Projects

- Regis High School: green roof totaling 22,000 ft² (5th largest green roof in NYC) with an onsite laboratory for students and storm water research by Columbia University (August 2010).
- Fashion Institute of Technology: pilot project totaling 14,000 ft² (July 2010).
- First to file and receive the New York City Green Roof Tax Abatement from PlaNYC (May 2010)
 - First to file and receive the New York City Green Roof Tax Abatement from PlaNYC (May 2010)



The completed roof at FIT



GREEN ROOFING TECHNOLOGY

M. ARAVIND

MBBS I YEAR

DSMCH, PERAMBALUR



Living roofs

Eco roofs

Vegetated roofs

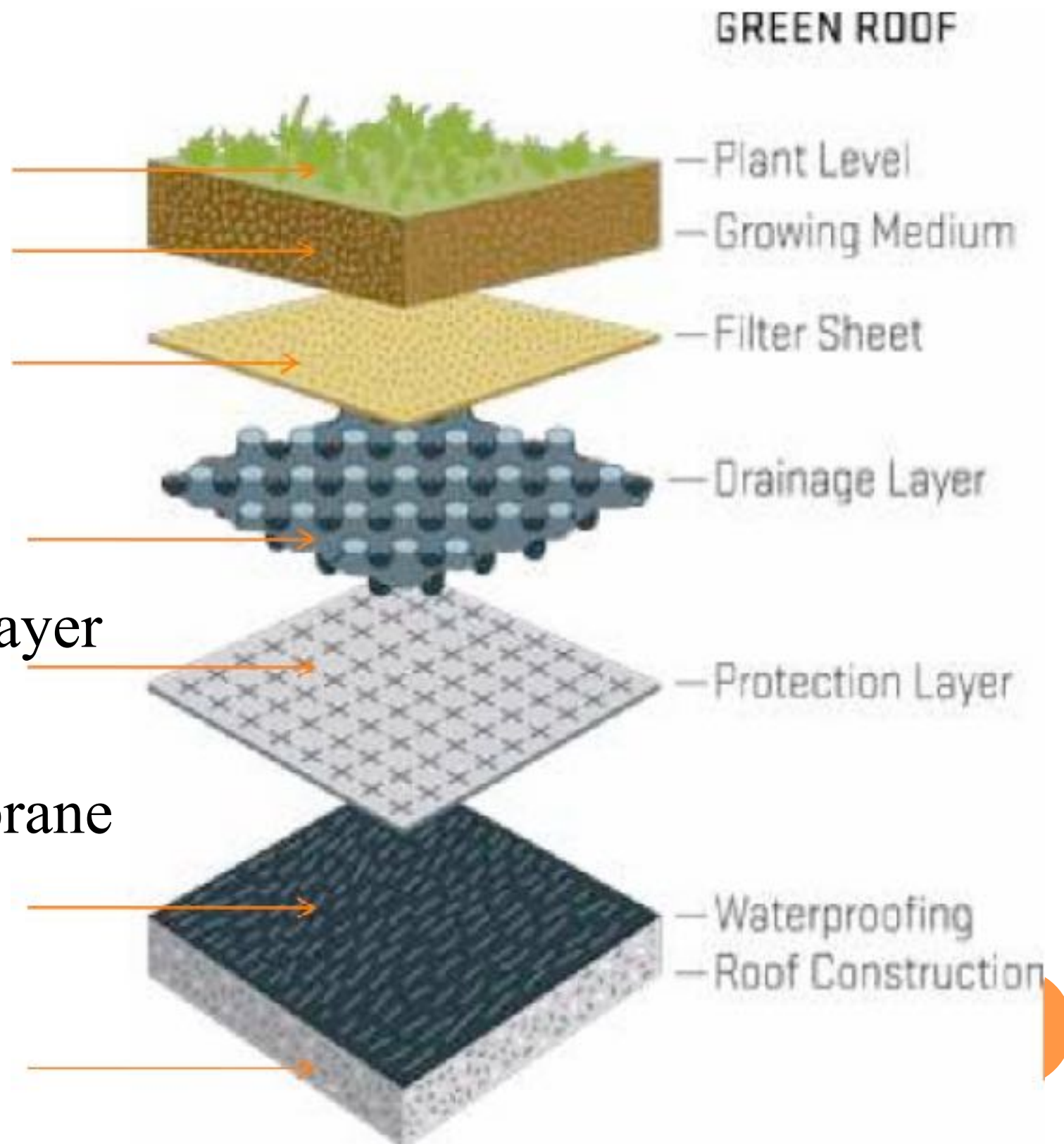
Roof gardens

DEFINITION:

- ❖ A green roof is a planted roof top
- ❖ Container gardens on roofs are not generally considered to be true green roofs.

LAYERS OF A GREEN ROOF (7 – 8)

- Vegetation
- Growing medium
- Filtration membrane
- Drainage layer
- Protection & storage layer
- Water proofing membrane
- Roof construction



ROOF CONSTRUCTION

- Can be constructed from wood, metal, concrete, plastic, gypsum, or composite
- Concrete decking will provide the **most sturdy roof structure**



WATER PROOFING MEMBRANE

- to protect the building from water penetration.

Some rubber and plastic sheet - applied and liquid - applied membranes meet these criteria



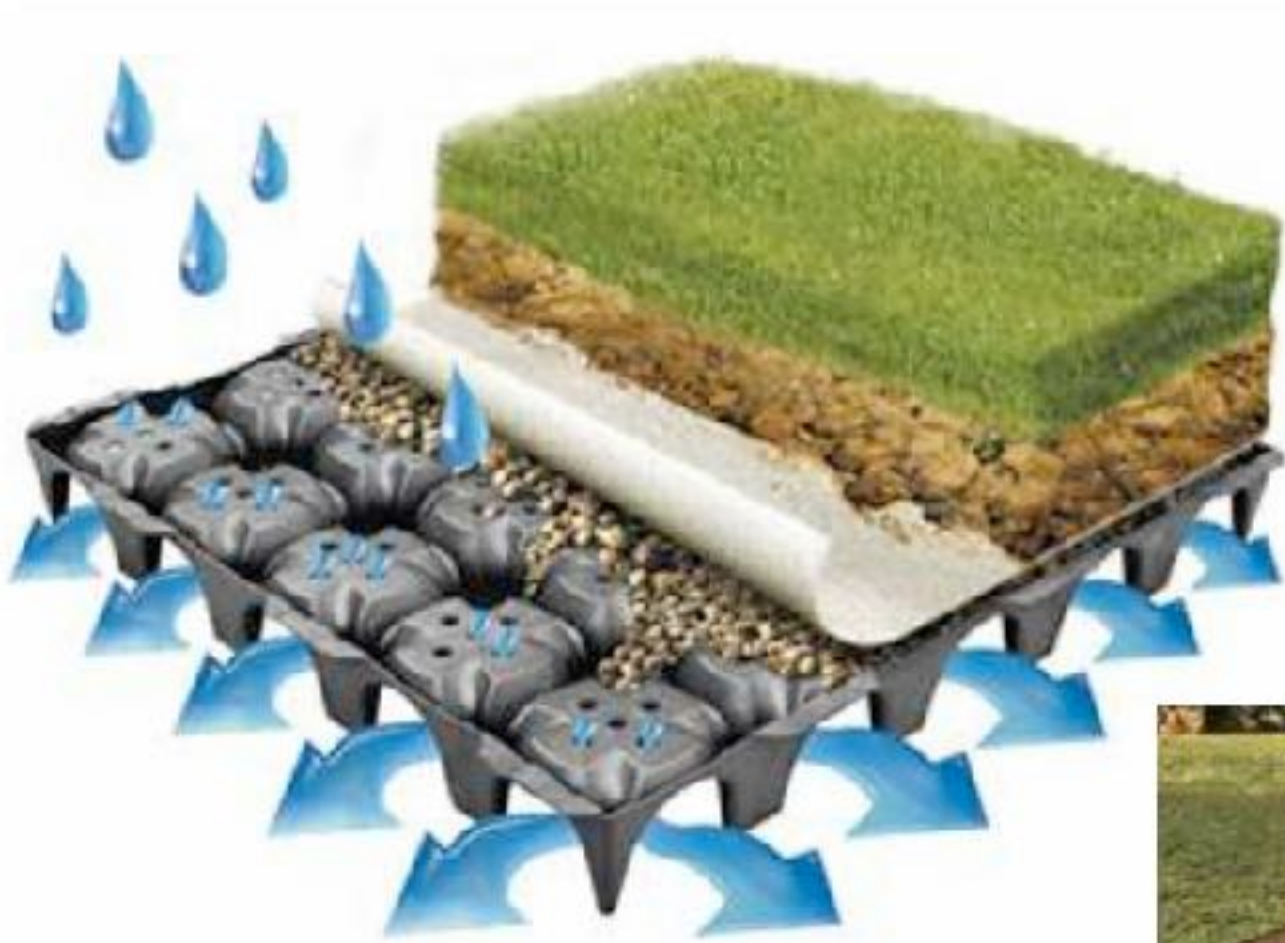
PROTECTION AND STORAGE LAYER

- To protect the roof membrane from aggressive plant roots.
- Mats with enhanced water storage and capillarity are preferred for some green roof systems.



DRAINAGE LAYER

- to help the excess water from the growing medium to flow to the roof drain.



FILTRATION MEMBRANE

- Allows excess water from the growing medium to flow out, while preventing the fine particles from washing away and clogging the roof drain.



GROWING MEDIUM

- **Engineered soil** : It must be lightweight, have good water storage characteristics, cheap
- **Organic composts are also included in it.**
- **Natural soil** : plants and insects adapt to it easily

SPEEDMAX



With an average flow rate of 35 cubic yard per hour it can reach as far as 500 yards and more.
ideal for large scale roof structures



VEGETATION

- minimal input plants should be selected (water, fertilisers, etc.)
- drought tolerant & cold tolerant
- Resistant to pests
- Low maintenance
- Root systems should be shallow.
- Self- perpetuating



HARDY SUCCULENTS

- best suited
- **Advantages:** can survive drought/ wind/ temperature extremes, store water for extended periods
- Only viable option for certain shallow soil extensive roofs

Coastal strawberry



Delosperma



Talinum

Sempervivum





S EDUMS



- Nearly 600 species available
- Found in well drained areas
- Long life span and self-propagating
- Change color with the seasons

HERBACEOUS PERENNIALS

- Added culinary and olfactory perks
- **Advantages:** aesthetically pleasing, lots of variety
- **Disadvantages:** Most have limited drought tolerance, will require deeper substrate, biomass accumulates as they grow, very few are evergreen

Dianthus



Petrorrhagia



Campanula



phlox

GROUNDCOVERS

- provide dense soil cover, retard weed growth, and prevent soil erosion
- Should be low density ground covers
- rapid and reliable growth at a reasonable price

NATIVES

- ❖ often function in an ecological system which makes their inclusion in green roofs somewhat difficult
- ❖ Advantages: already adapted to local weather conditions, resistance to local pests etc.



GRASSES



TYPES (3)

INTENSIVE GREEN ROOFS

- Structural requirements:
structural improvements
necessary
- Irrigation: often require irrigation
- Maintenance: same
maintenance requirements as
similar garden at ground level
- Cost:
- Accessibility: less prevalent

EXTENSIVE GREEN ROOFS

- Structural requirements: typically within standard roof weight bearing parameters
- Irrigation: most require little or no irrigation
- Maintenance: little or no maintenance required; some weeding or mowing as necessary
- Accessibility: generally functional than accessible.

Most prevalent



SEMI-INTENSIVE GREEN ROOFS

SEATTLE ART MUSEUM



VANCOUVER PUBLIC LIBRARY



- Between intensive and extensive green roofs regarding maintenance and support capacity



ADVANTAGES

○ ENERGY

EFFICIENCY

- significantly reduce roof surface temperatures and heat flux rates (energy passing through a unit area per unit time).
- A study in Toronto: green roofs with minimal vegetation reduced peak summer time heat flow by 70 to 90%.



STORM WATER RUNOFF

- extensive roofs will typically capture between 50 - 85% of incoming rain
- depends on amount of growing medium, density of vegetation, the intensity of rainstorm, and the frequency of rain

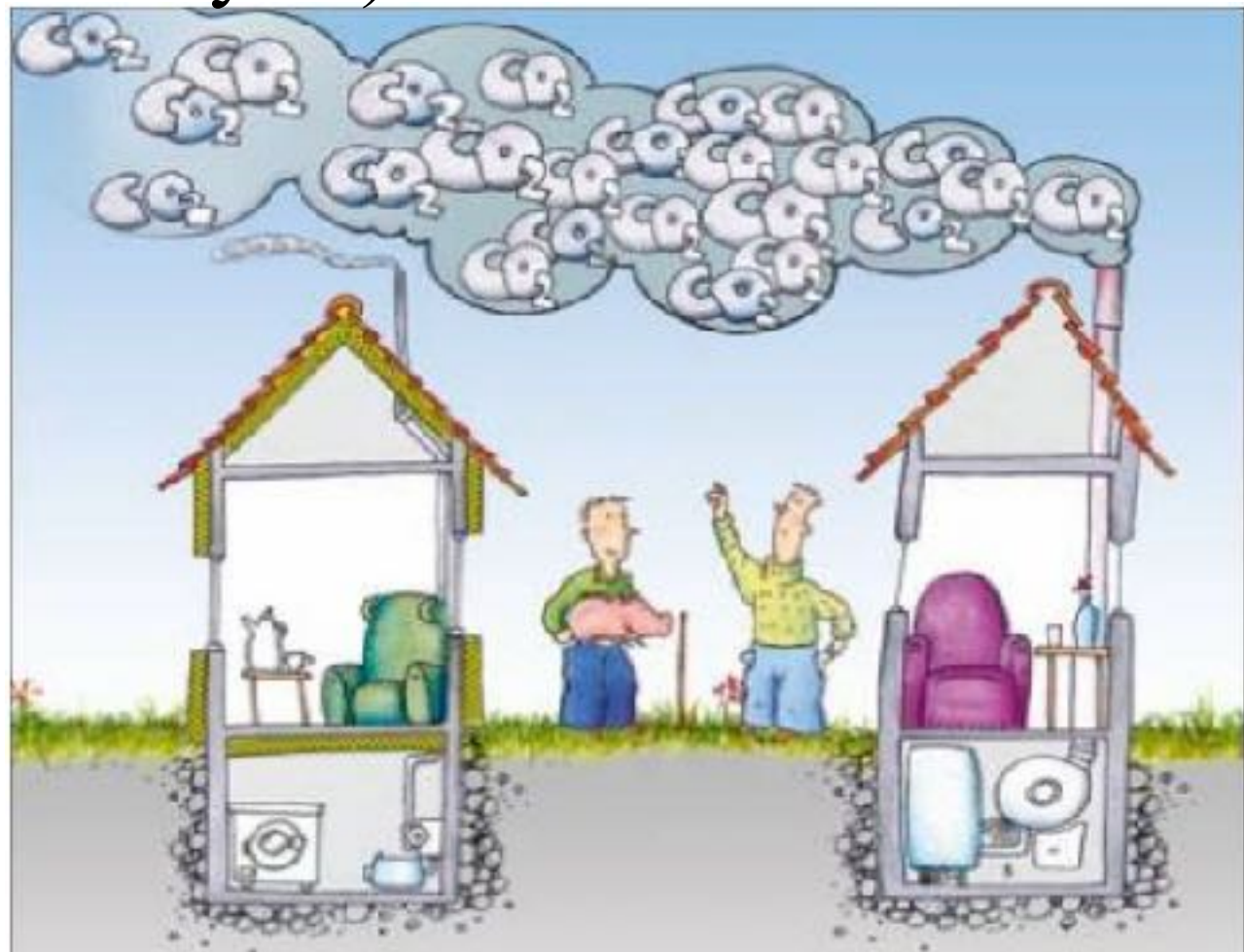


R EDUCES AIR POLLUTION

- removes particulate matter (PM) and gaseous pollutants including nitrogen oxides (NOX), sulphur dioxide (SO₂), carbon monoxide (CO), and ground-level ozone (O₃)
- Researchers estimate that a 1,000 - sq. Ft. (93 sq. m) green roof can remove about 40 pounds of PM in a year (15 cars will emit in a year)

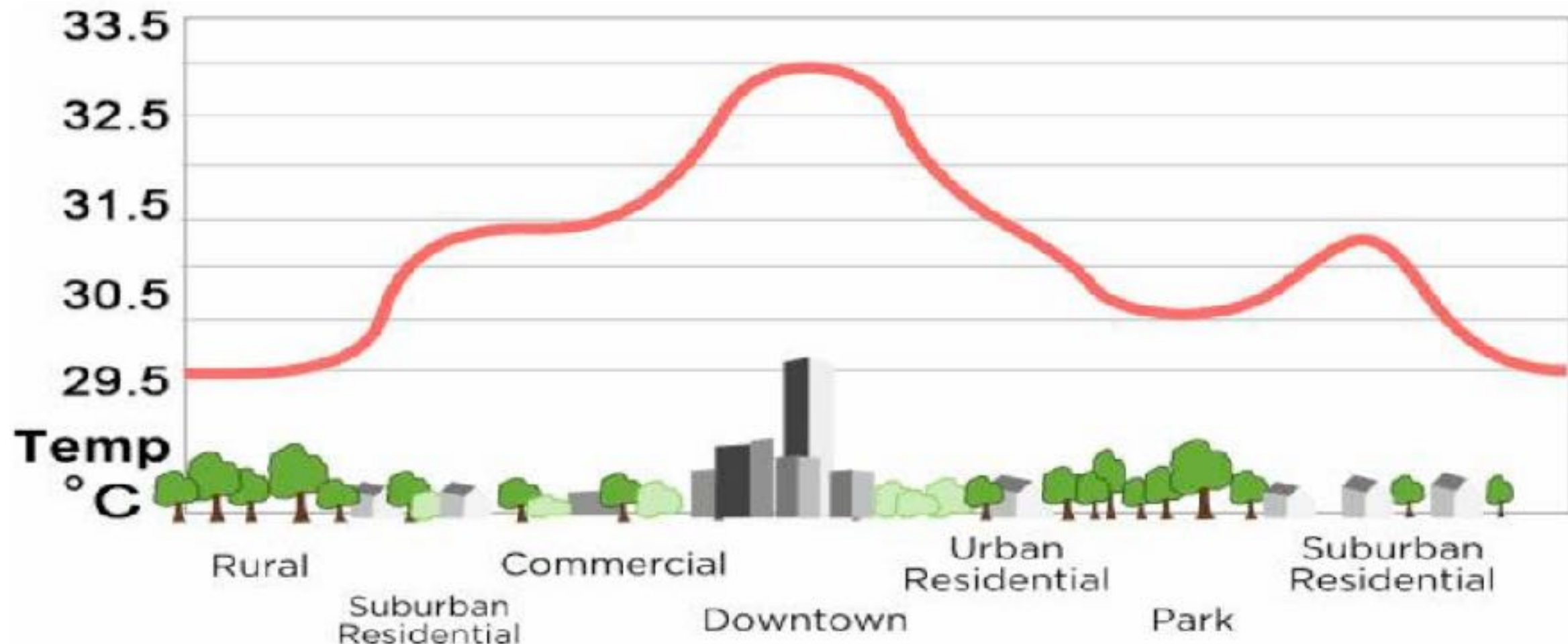
REDUCE CO₂

PRODUCE O₂



REDUCE URBAN HEAT ISLAND EFFECT

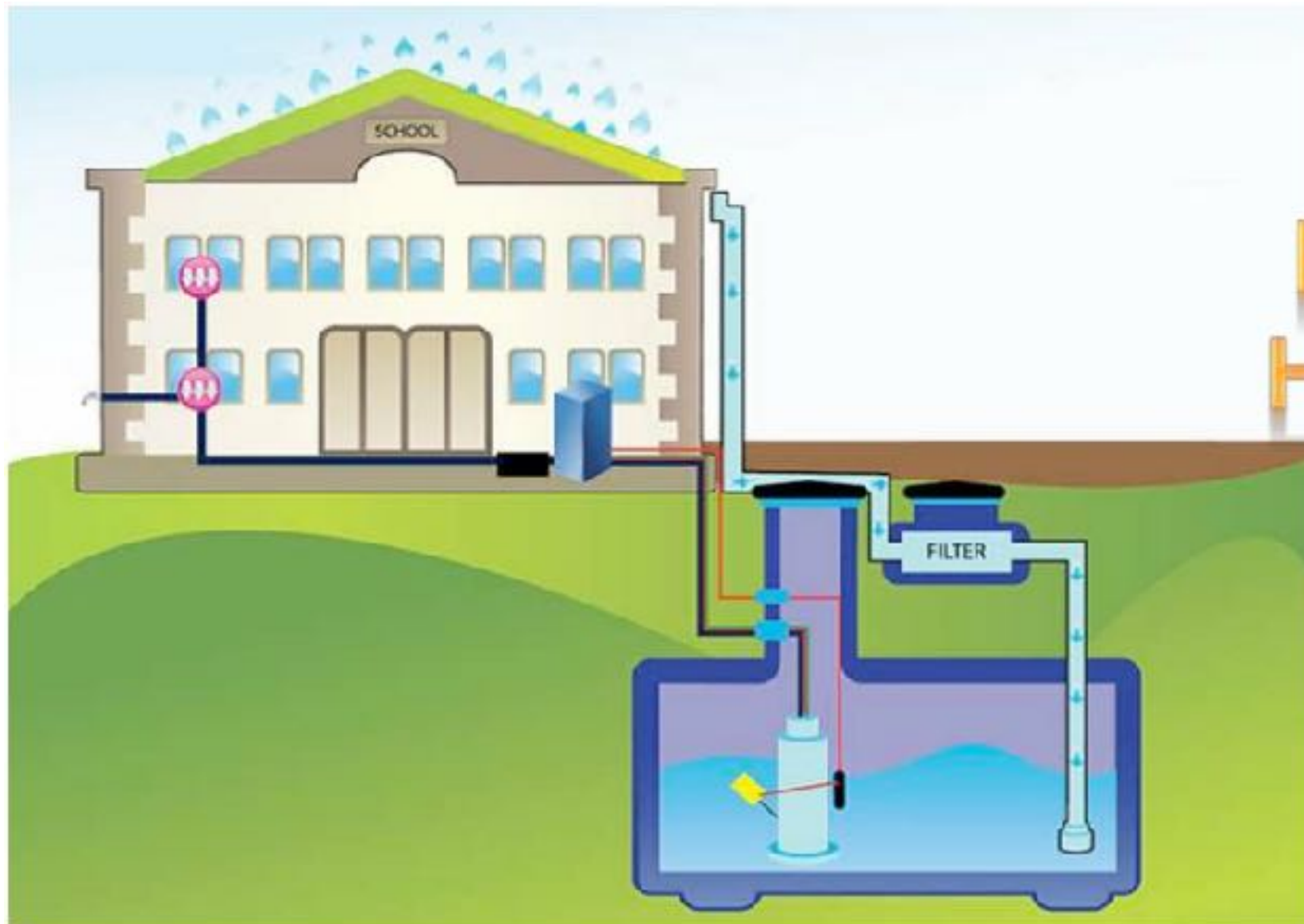
- Cities can be 2 degrees to 8 degrees warmer than surrounding environments (rural) due to the large areas of dark surfaces. Due to lack of green spaces the extra heat cannot escape into the atmosphere. This phenomenon is urban heat island effect
- lower temperatures by 3.6 to 11.3°C depending on the city.



REDUCES NOISE POLLUTION

INCREASES LIFE OF THE ROOF

- by preventing degradation from solar radiation



RAINWATER
HARVESTING

BROWN ROOF

- It supports rare species of animals, birds and invertebrates
- Contributes to biodiversity and creates habitats

KILL DEERS



LADY BUG



BIRDHOUSE WITH GREENROOF



The Fairmont Waterfront Hotel, Canada

FOOD PRODUCTION



WATER TREATMENT



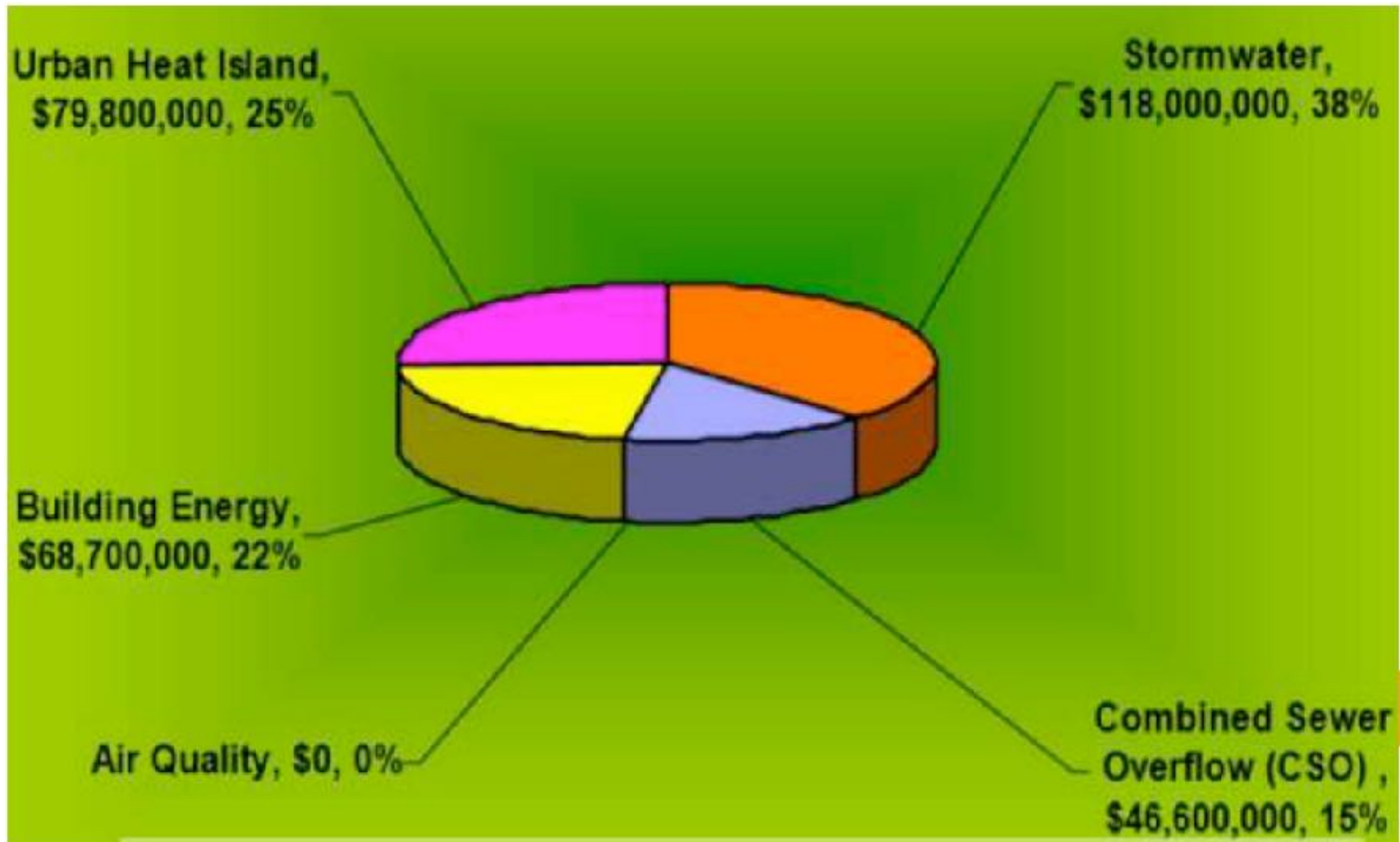
DISADVANTAGES

- Initial cost of installation is high
- Pest insects could easily infiltrate a residential building through open windows
- For intensive green roofs there is additional cost of reinforcing the building
- Based on the green roof types, the maintenance work and the cost of installation are high

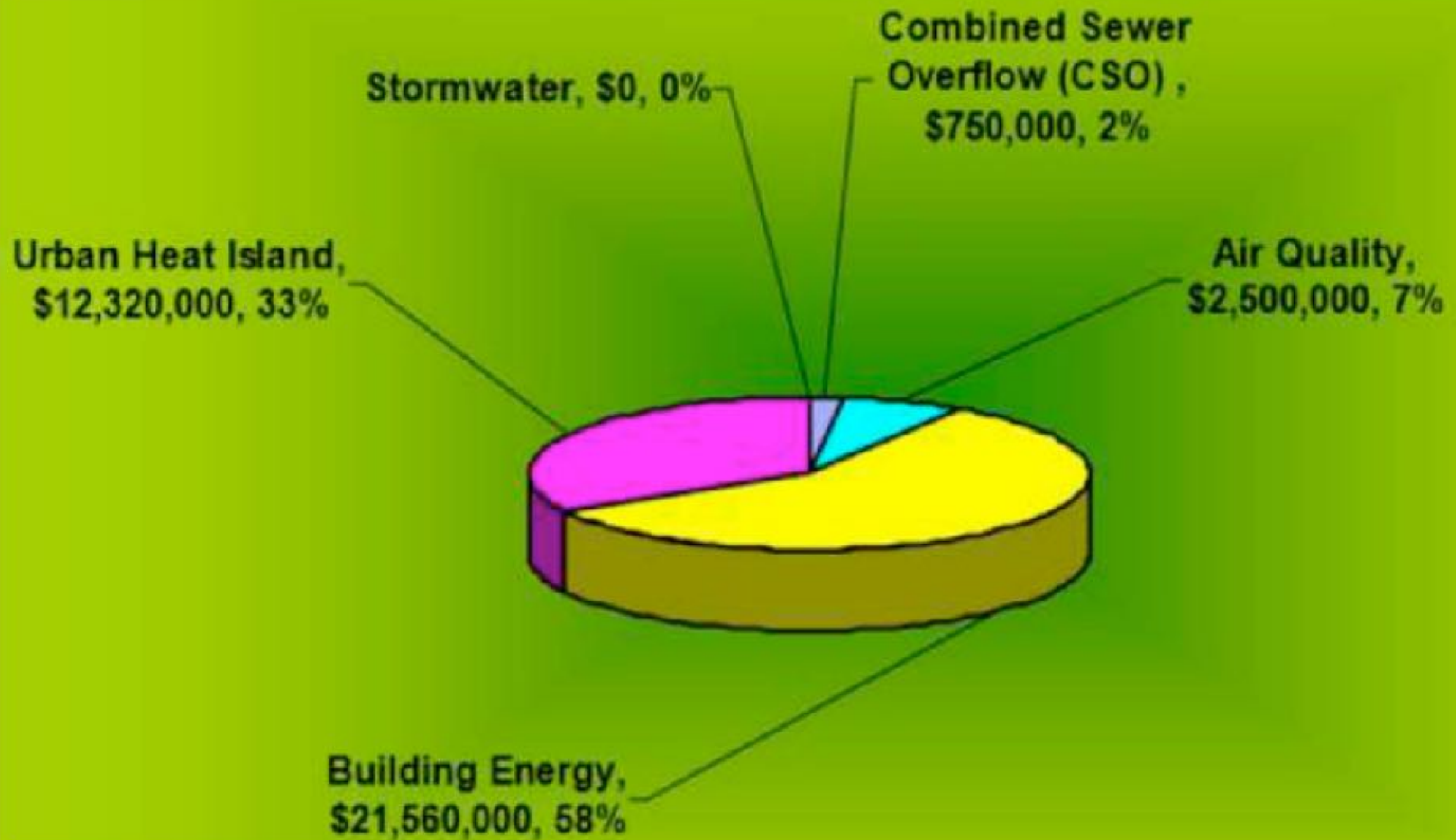
COSTS AND FINANCIAL BENEFITS

- Extensive green roof: Rs . 110 - 150
- Intensive green roof: Rs . 210 - 250

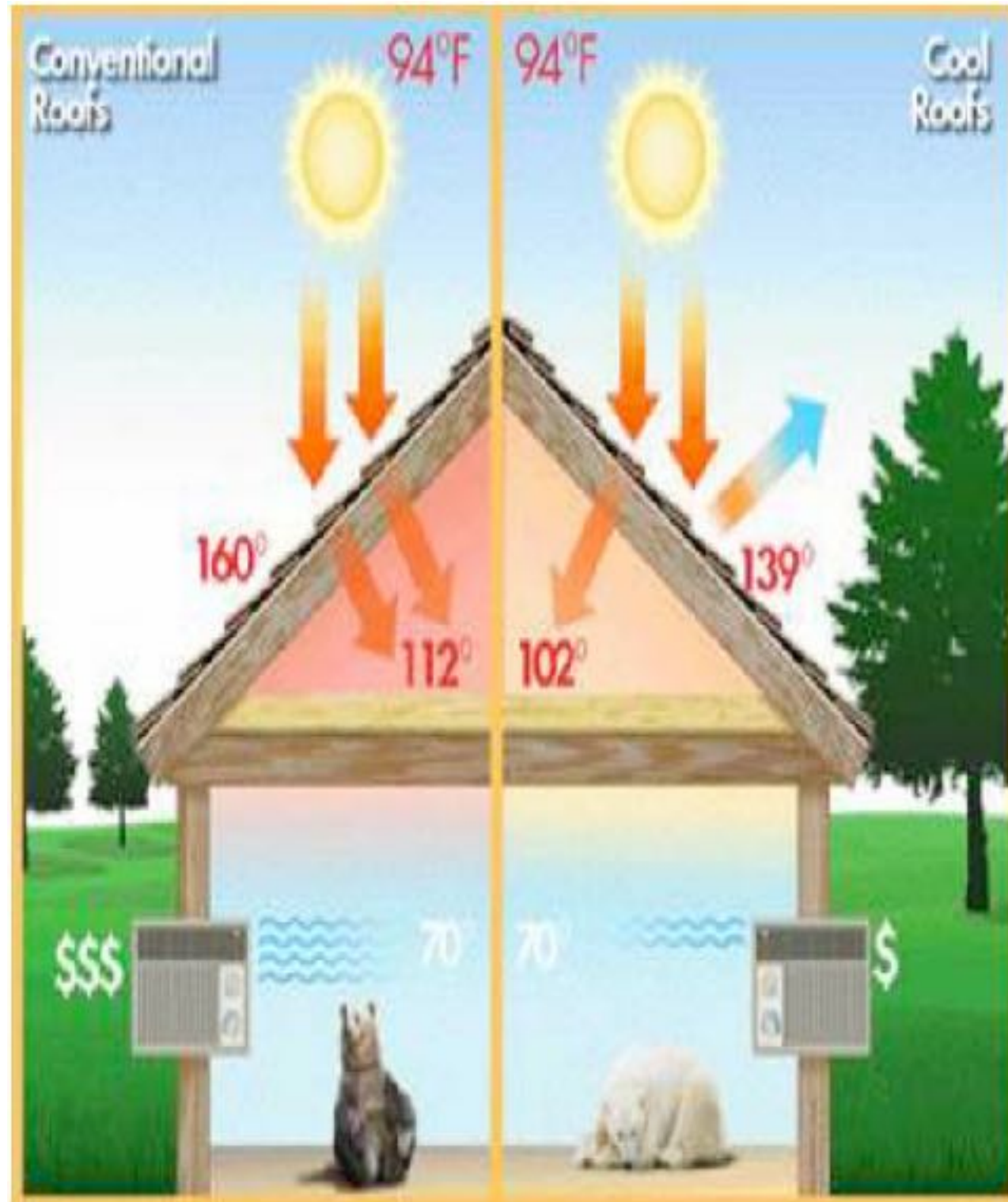
INITIAL SAVINGS



ANNUAL SAVINGS



REDUCTION IN ENERGY USE



- allows buildings to retain heat during winter months while reflecting and absorbing solar radiation during the hotter summer months.
- reduce building temperatures by up to 20 °C & reduce energy needs for air - conditioning by 25% to 80%.
- Reduce energy to heat a building in the winter.

LIFE SPAN OF ROOF

- can extend by over 200%
- increase the real estate value of an average house by about 7%.

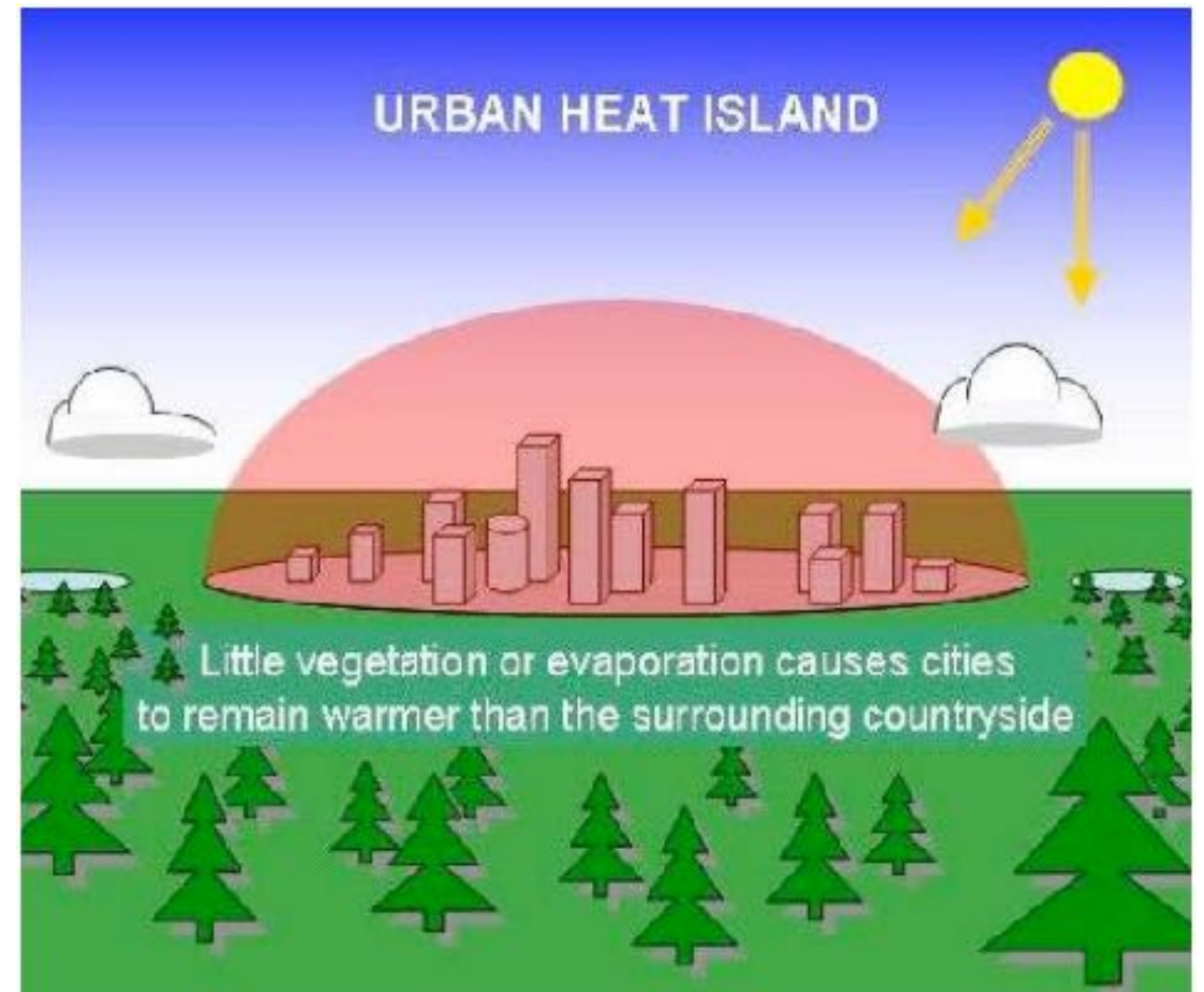
INCENTIVES

- Air pollution
- significant urban heat island effect
- Stormwater runoff is of great concern
- Eg : one- year property tax credit is available in New York City, since 2009, for those who green at least 50% of their roof area.

NEED OF GREEN ROOFS

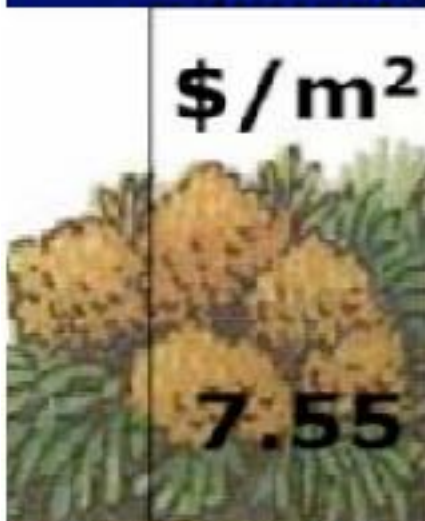









- Over 50% of the world's population currently lives in urban areas. This is expected to increase to 70% by 2040 .

The WHO recommends 9 sq. m open space per city dweller should be minimal norm for a city. Gandhinagar - 162 sq. m per dweller green space, Chandigarh - 54 sq. m, Delhi - 21 sq. m, Bangalore - 17 sq. m and Chennai - 0.46 sq. m per city dweller. In such a situation, “green roofs” is the only way to offset this problem



INCENTIVES AND MANDATES

- Germany : 15 euros /m² of green roof
- Switzerland : 25 % new commercial development should be greened
- Chicago is at the fore front

| Germany | | USA | | Material prices incl. shipping (150 miles) |
|--|------|---|-------|--|
| \$/m ² | | \$/m ² | | |
|  | 7.55 |  | 12.15 | ← Plugs 1,5 pcs/ft ² |
|  | 3.60 |  | 15.95 | ← Growing medium 4" deep |
|  | 0.85 |  | 2.10 | ← Filter Fabric 9 oz/yd ² |
|  | 5.05 |  | 12.90 | ← Drain Plate 1" |
|  | 1.45 |  | 4.20 | ← Protection Fabric 15 oz/yd ² |
| 18.50 | | 47.30 | | |

GREEN ROOF COVER IN DIFFERENT PARTS OF THE WORLD

- Dusseldorf, Germany
- Stuttgart , Germany
- Basel, Switzerland
- London, England
- Portland Oregon
- Chicago, Illinois



GREEN ROOFS IN BASEL, SWITZERLAND

STUCKISHOPPING CENTER GREEN ROOF

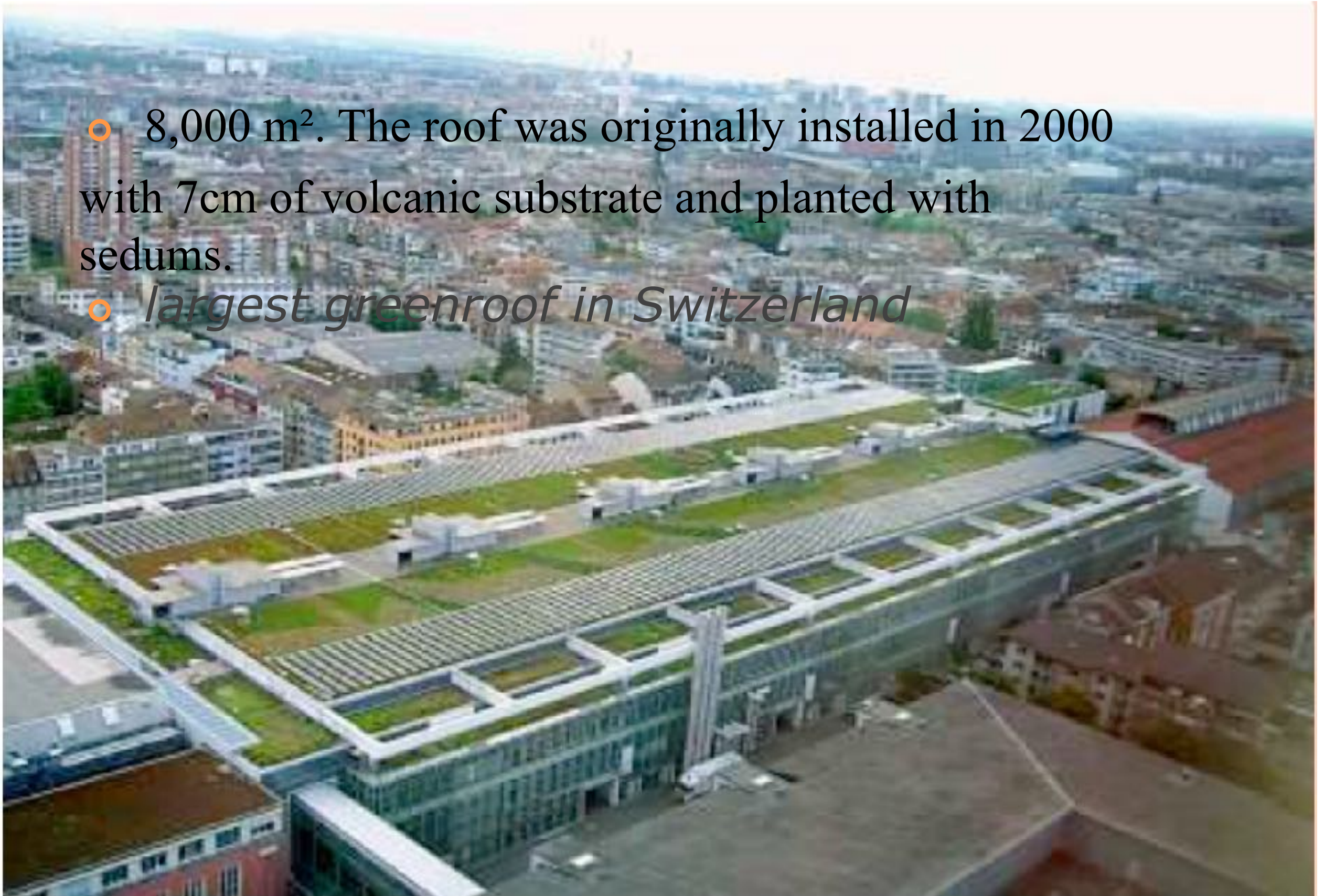


CANTONAL HOSPITAL GREENROOF



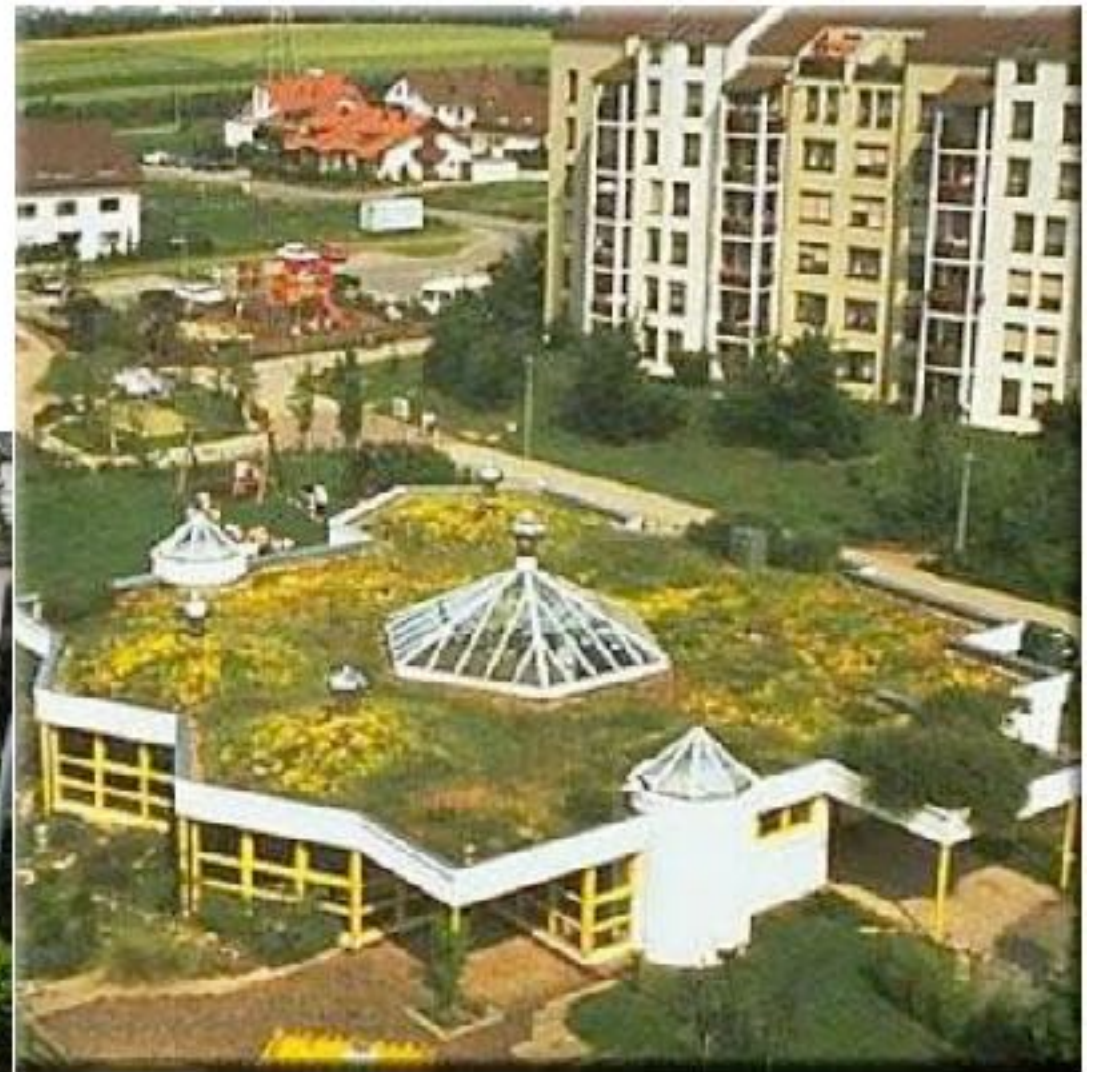
BASEL MAIN EXHIBITION HALL (MESSEHALLE BASEL) GREEN ROOF

- 8,000 m². The roof was originally installed in 2000 with 7cm of volcanic substrate and planted with sedums.
- *largest greenroof in Switzerland*



GREEN ROOFS IN STUTT GART, GERMANY

one of the first cities to pass a law mandating that every new flat topped building be planted with a green roof



JAPAN

❖ Tokyo's historic Imperial Hotel Tokyo





GREEN ROOFS IN USA

Brooklyn Grange (vegetable farm)



California academy of sciences building in San francisco (sloped roof)



CANADIAN WAR MUSEUM



GREEN ROOFS IN SINGAPORE

The Parkroyal Hotel(15,000 sq m)



The School of Art, Design and Media



ACROS FUKUOKA PREFECTURAL INTERNATIONAL HALL



GREEN ROOFS IN LONDON

London Zoo.



Beaufort Court



GREEN ROOFS IN TORONTO

Mountain Equipment Co-op



GREEN ROOFS IN INDIA

Vintava hotel, Bangalore



Here's a volunteer green roof. Who says green roofs are high maintenance?



THANK YOU

