# An Introduction to Green Roof Technology

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# The Challenge

**Eliminate reliance on fossil fuel**

$CO_2$ emissions/greenhouse gas
Reliance on/funding of authoritarian regimes
Unstable supply
Need for new technology growth markets

**Use water more efficiently**

1.4 billion people lack access to clean water
waterborne disease kills a child every 8 seconds)
20% more water will be needed for agriculture by 2025
"world water gap"
Alternative water supplies needed in Central Florida within the next 5-6 years (SJWMD)

**Better design of buildings which, in U.S., consume or produce:**

70% of the electricity
65% of solid waste
30% of greenhouse gas emissions
17% of potable water

US Green Building Council

# The Solution

## Visualize a robust, sustainable future

"I believe we can accomplish great and profitable things within a new conceptual framework—one that values our legacy, honors diversity, and feeds ecosystems and societies . . . It is time for designs that are creative, abundant, prosperous, and intelligent from the start."

William McDonough

## Engage a majority of the population in the process

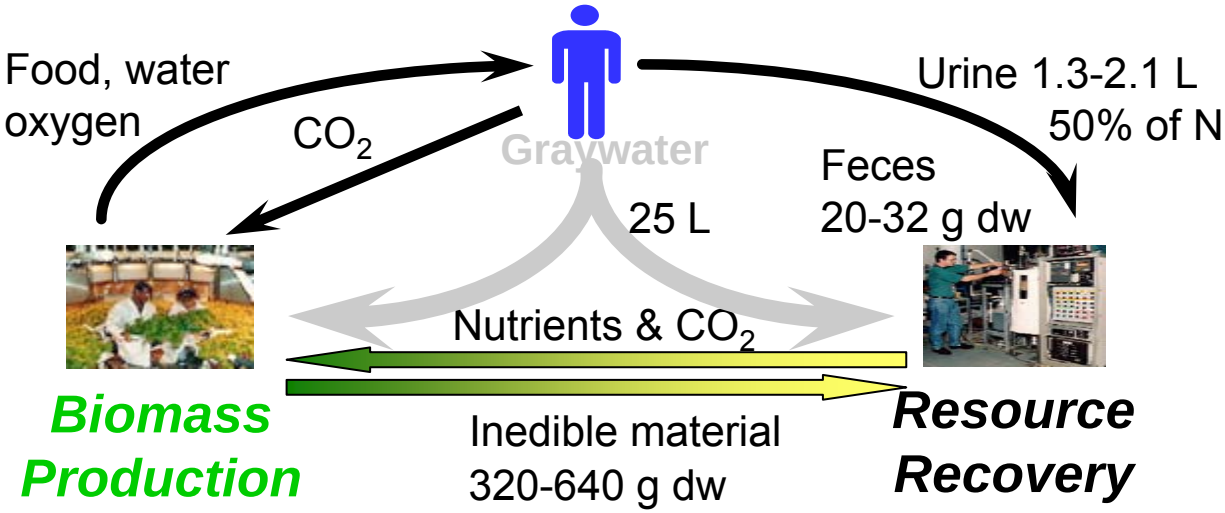
"Human history becomes more and more a race between education catastrophe."

H.G. Wells

# Presentation Overview

- Personal Background
- Green Roof
  - Definitions and components
  - Examples
  - Benefits
  - Current Status and Future directions

# Bioregenerative Life Support



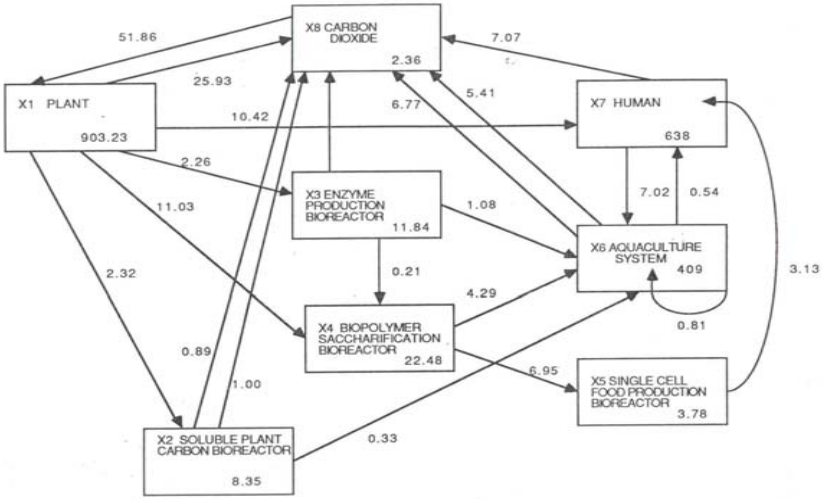




Figure 1. Flow diagram of carbon in a CELSS. Boxes represent reservoir size (g C/sq. meter growing area), arrows represent flux rates (g C/sq. m./day).

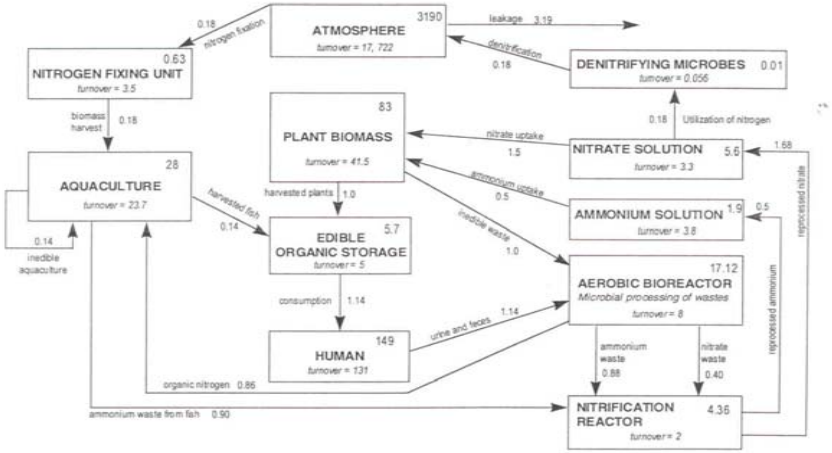
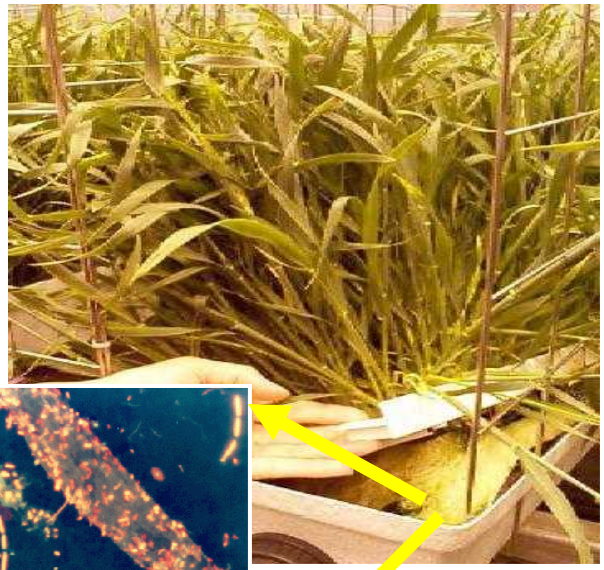
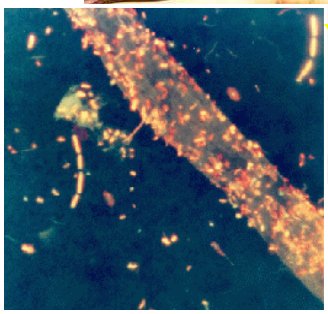



Figure 1. Schematic representation of the initial mathematical model of the nitrogen cycle in a closed bioregenerative life support system. The arrows represent the fluxes and the objects represent the reservoirs. The numbers associated with each represent the inital values. Flux values are presented in moles of nitrogen per person per day, whereas reservoir values are presented in moles of nitrogen per person. Turnover rates are represented in days (italic type).

# Direct Graywater Processing Scheme





Transpiration

Condensate

Surfactant Degradation in the Rhizosphere

Graywater addition as liquid level replenishment

Maintenance of water quality

# Advanced Technologies for On-site Wastewater Treatment

## Root Zone Enclosed Plant Units

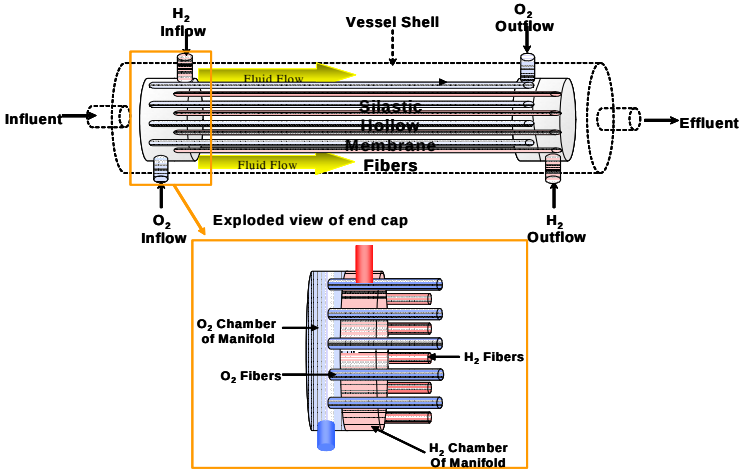
**Day 7**

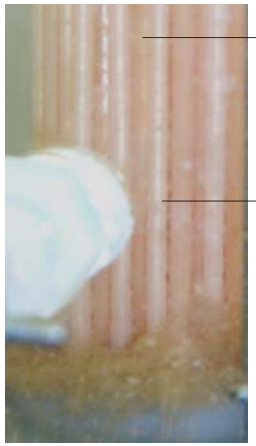
**Day 258**

**Day 148**

**Day 391**

## Hollow Fiber Membrane Biofilm Reactors



Aerobic Processes ($O_2$ diffusion)

Nitrification

$2NH_4^+ + 3O_2 \rightarrow 2H_20 + 4H^+ + 2N0_2^-$

$2NO_2- + O_2 \rightarrow 2NO_3^-$

Hydrogenotrophic Processes ($H_2$ diffusion)

Denitrification

$2NO_2- + 2H^+ + 3H_2 \rightarrow N_2 + 4H_20$

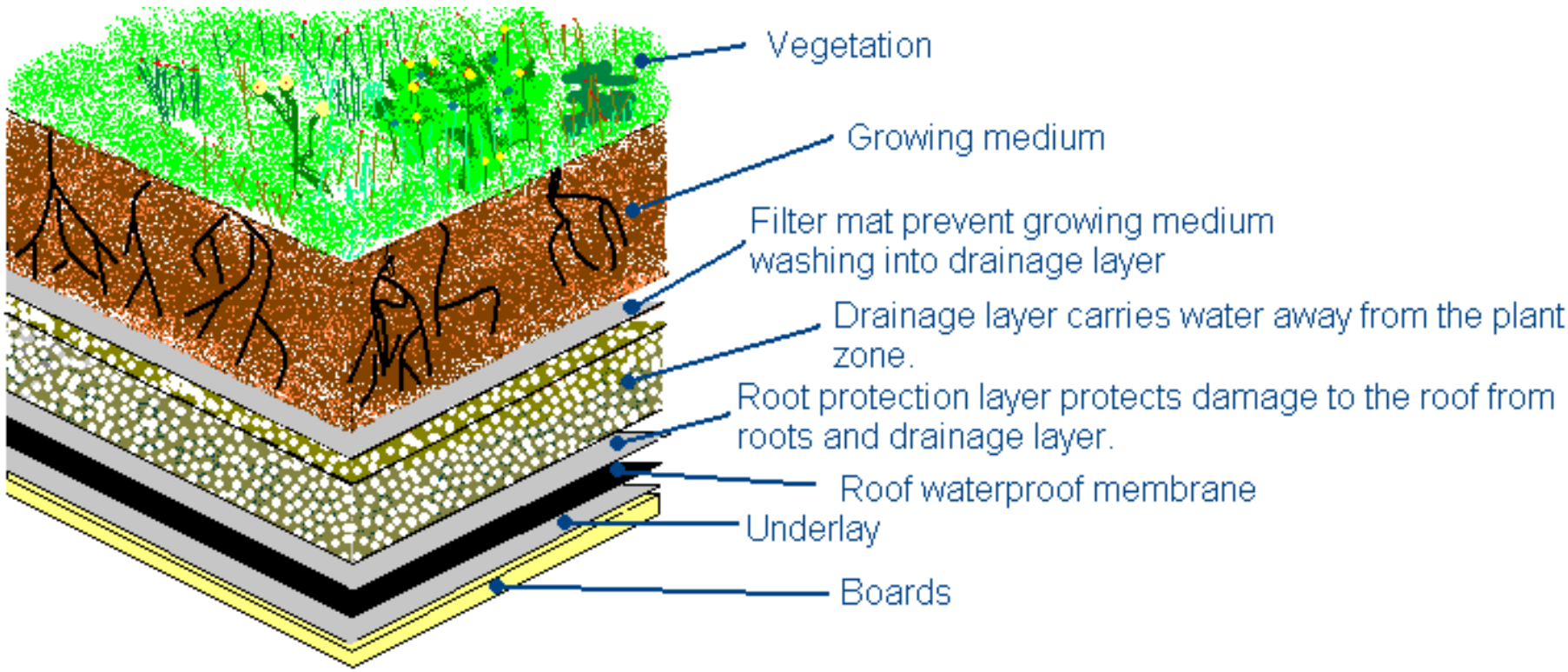
$NO3- + H2 \rightarrow NO_2^- + H_20$

Simultaneous processes to purify $NH_4$-rich wastewater

# Definitions

- Green roof
  - not green colored shingles
  - not solar photovoltaic panels
  - also called an “eco-roof” or “living roof”; an extension of the existing roof, covered (to some degree) with vegetation.
  - Typically contains:
    - a synthetic, high quality waterproof membrane
    - drainage layer
    - soil layer and
    - plants

# Basic Components of Green Roof



# Membranes

- **Hydrotech, Inc. (Chicago, Ill.)**
  - **Monolithic Membrane 6125 (MM6125®)**
    - Thick, flexible, self-healing membrane for use in waterproofing and roofing applications
    - Special formulation of refined asphalts and synthetic rubbers
    - Hot fluid applied

# Media

- Lightweight with high water holding capacity
- Examples
  - Expanded Clay (firing clay, shale, or slate at >2000°F in rotary kiln)
  - Mixtures of expanded clay + peat moss/perlite/vermiculite
  - Mixtures containing recycled products
    - Up to 40 % Black and Gold (crumb tire)
    - Shredded polystyrene
    - Compost

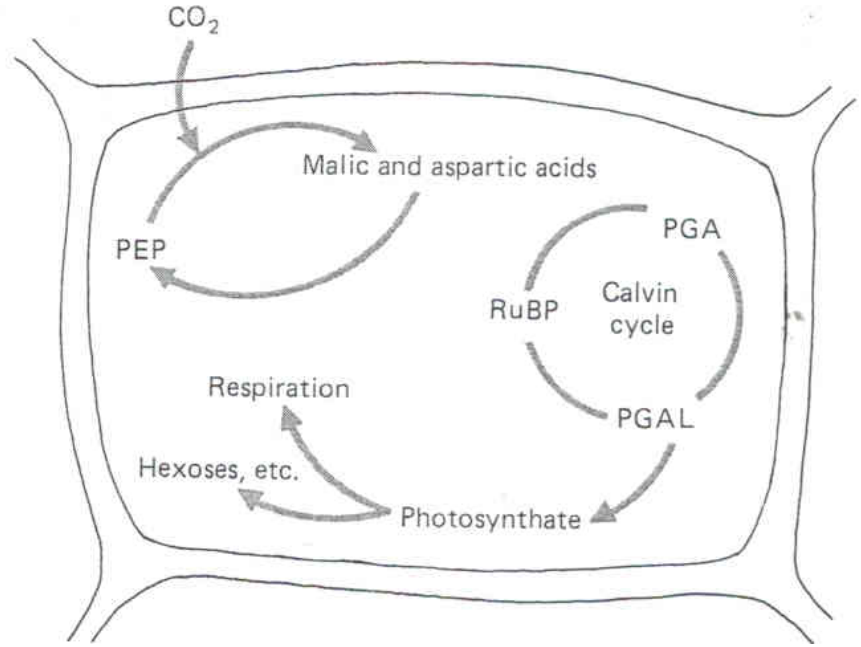
# Plants

- Wide range of plant types used (from grass to trees)
- Succulents (e.g., Sedum) commonly used
- Native and non-native designs
- Highly dependent on type of application

Elevated Landscape Technologies (ELT)
Ontario, Canada

Pre-grown, modular green roof technology

# Crassulaceae or succulents (including Sedum sp).




Adaptation to low water conditions (succulents)

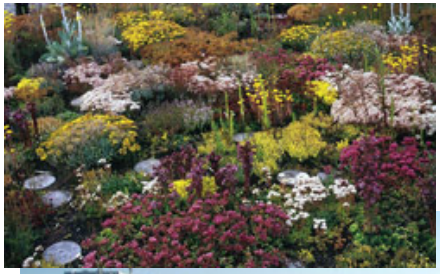
Stomates open at night and build up malic and aspartic acids,
Close during day and run Carbon cycle from stored sugars

Slow growth as the trade-off for water conservation

# Types of Green Roof

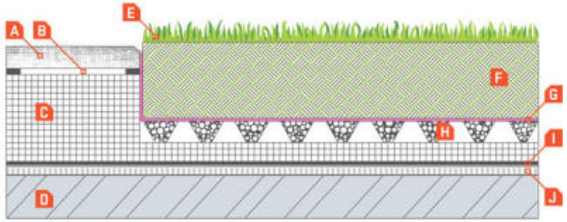
## International Green Roof Association (igra-world.com)

| | Extensive Green Roof | Semi-Intensive Green Roof | Intensive Green Roof |
|---|---|---|---|
| **Maintenance** | Low | Periodically | High |
| **Irrigation** | No | Periodically | Regularly |
| **Plant communities** | Moss-Sedum-Herbs and Grasses | Grass-Herbs and Shrubs | Lawn or Perennials, Shrubs and Trees |
| **System build-up height** | 60 - 200 mm | 120 - 250 mm | 150 - 400 mm on underground garages > 1000 mm |
| **Weight** | 60 - 150 kg/$m^2$<br>13 -30 lb/sqft | 120 - 200 kg/$m^2$<br>25 - 40 lb/sqft | 180 - 500 kg/$m^2$<br>35 - 100 lb/sqft |
| **Costs** | Low | Middle | High |
| **Use** | "Ecological protection layer" | "Designed Green Roof" | "Park like garden" |



Some examples…..

# Fox Residence in Chicago

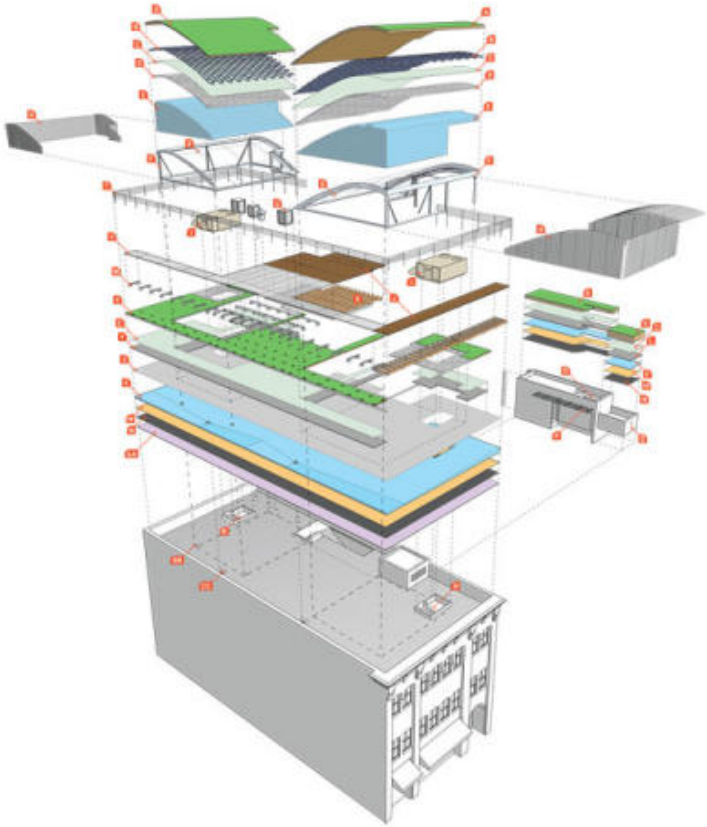


$60K investment

Hydrotech  membrane to eliminate leakage

7-10” of soil

# American Society of Landscape Architects (Washington, D.C.)



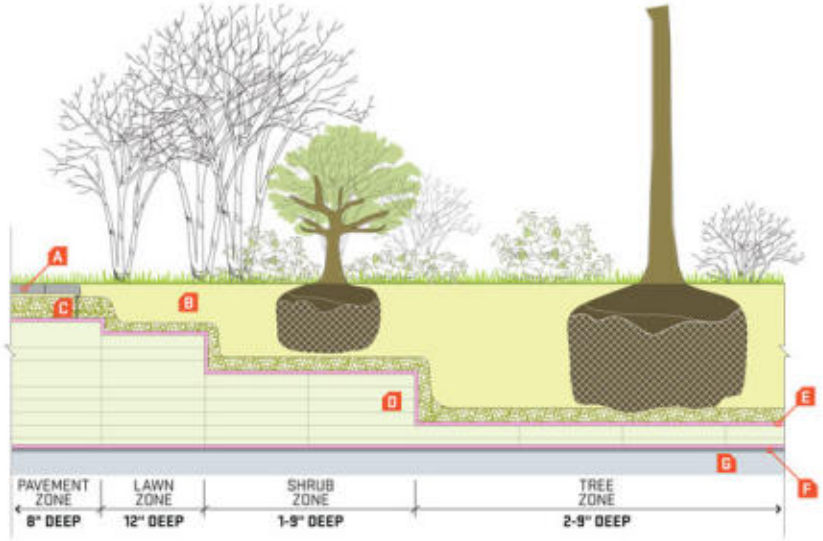
3,300 sq ft.

Waves to maximize visibility from street

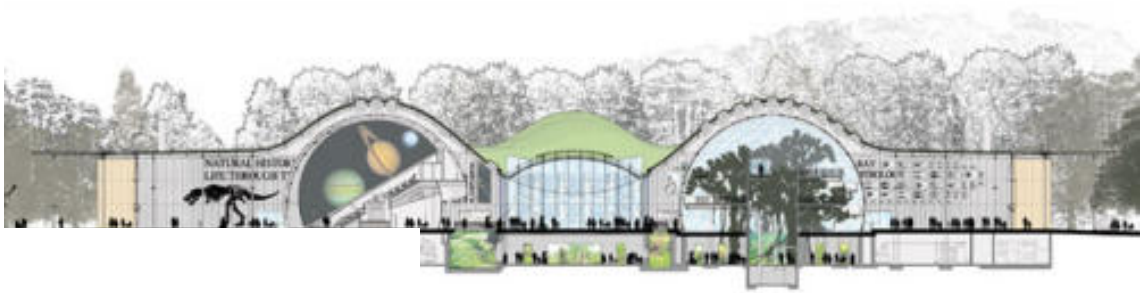
# Boston General Hospital

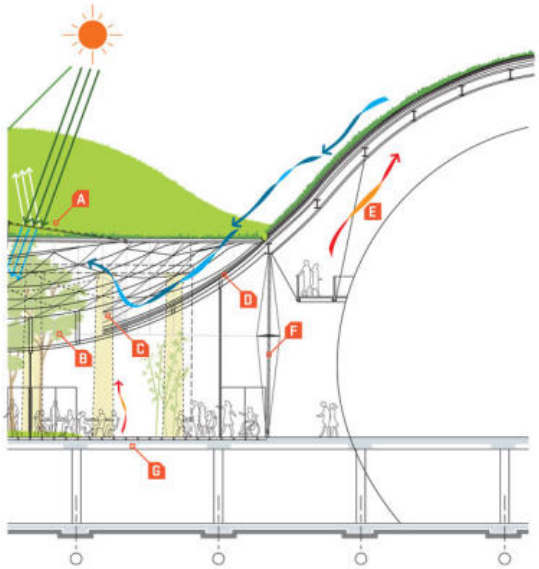
6,500 sq. ft  “healing garden”

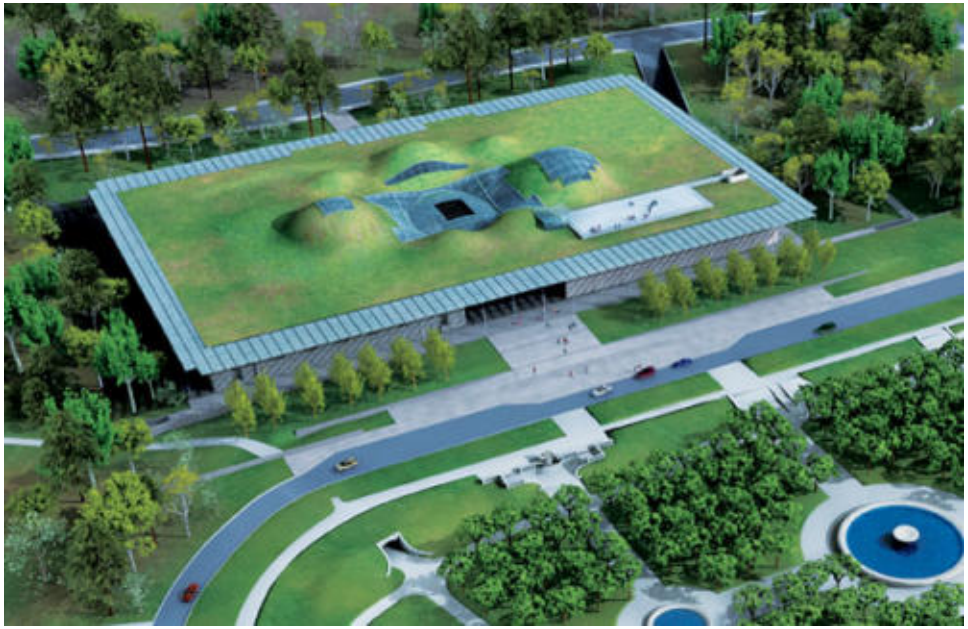
8-36” soil depth



# California Academy of Sciences (San Francisco)





2.5 acre rolling garden with slopes up to 60°

Intensive selection of native California plates (final set of 8 from 36 tested)

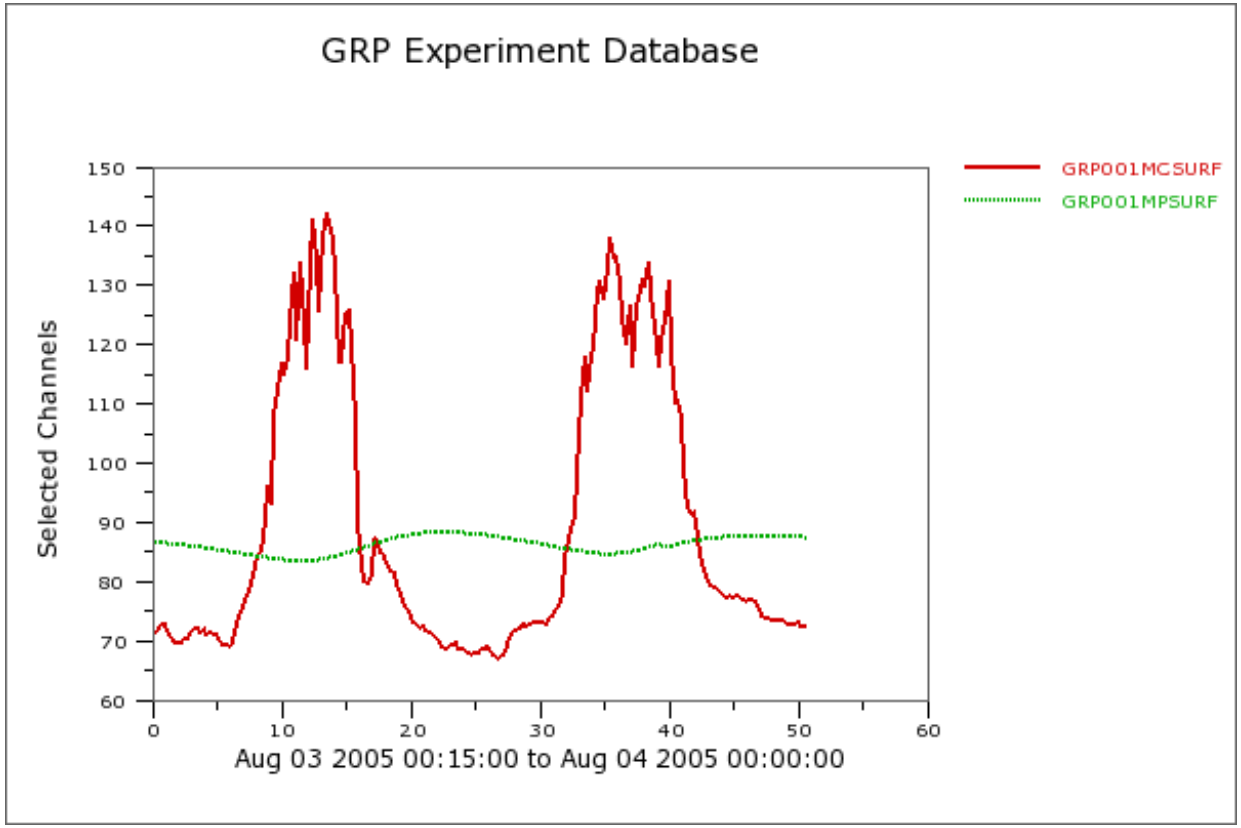
# Benefits of Green roofs

- Private
  - Increased roof life (2-3 fold)
  - Reduced heating and cooling costs
  - Reduced noise
  - Creation of “living” space
  - Food production
- Public
  - Stormwater retention
    - Reduced volume, improved quality (removed nitrogen, neutralize acid rain)
  - Reduce urban heat island effect
  - Reduction of dust and smog
  - Reduce $CO_2$
  - Provides wildlife habitat

# Fairmount Hotel Vancouver

Savings of 30,000/year by growing herbs, vegetables, and flowers

# Cooling Effects of Green Roof




Source: [www.stormwater.ucf.edu](http://www.stormwater.ucf.edu) and click on roof monitoring data

# Linking “Wastewater” Processing and Green Roof

Irrigation greatly increases the cooling capacity of green roofs (by up to 400% according to Bass and Baskaran (2002)

Plant roots are extremely efficiently “bioreactors” for the processing of organic matter

- large community of associated microorganisms

Potential sources of irrigation water

- captured rainwater (cistern)
- graywater (wastewater from laundry, shower, sinks)
- air conditioning condensate

Potential reuse within the home for non-potable uses (“green water”)

- other landscape irrigation
- toilet flushing

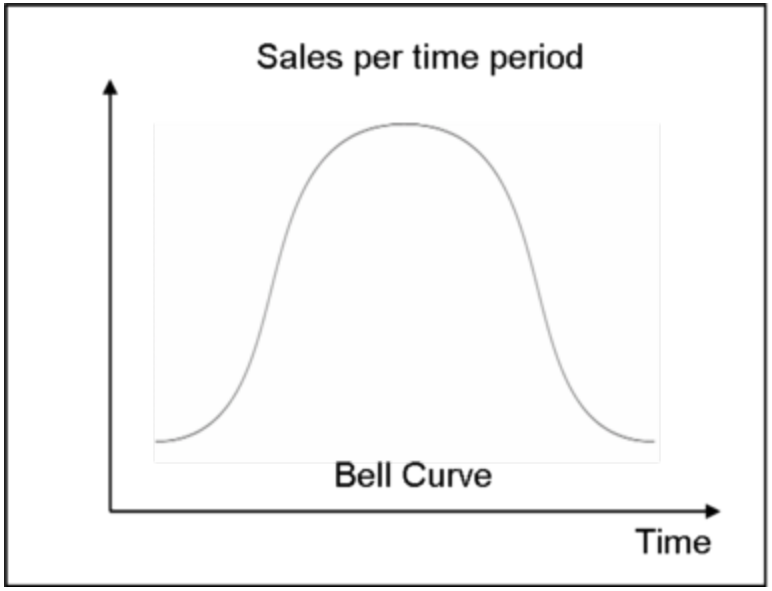
# Green Roof Costs

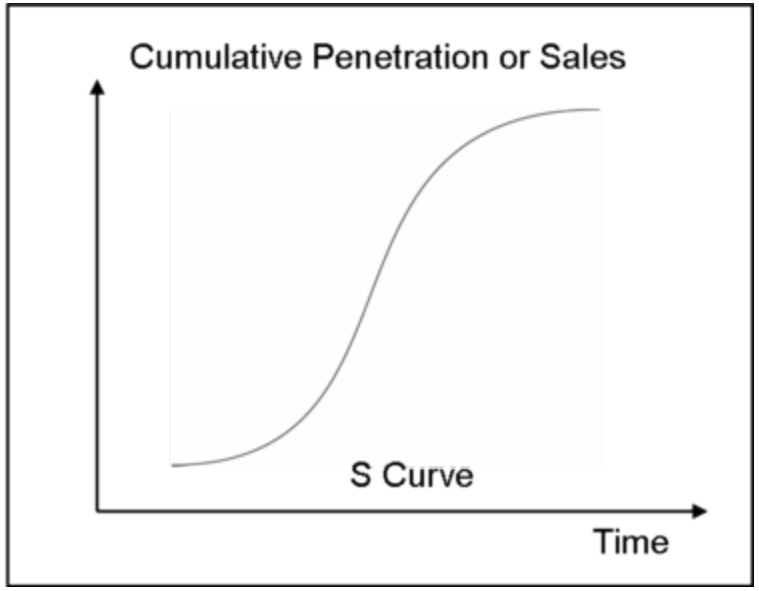
- Typically range from $10-24 sq ft (compared to conventional costs of $5-10 sq ft)
- If roof costs alone are considered, green roofs are no more expensive than conventional
- But if full impacts are considered, green roofs appear to be the clearly sustainable choice
  - Both direct savings for homeowner
    - decreased energy costs, higher property value
  - And indirect effects
    - lower cooling costs due to reduction in Urban Heat Island effect
    - reduced stormwater runoff

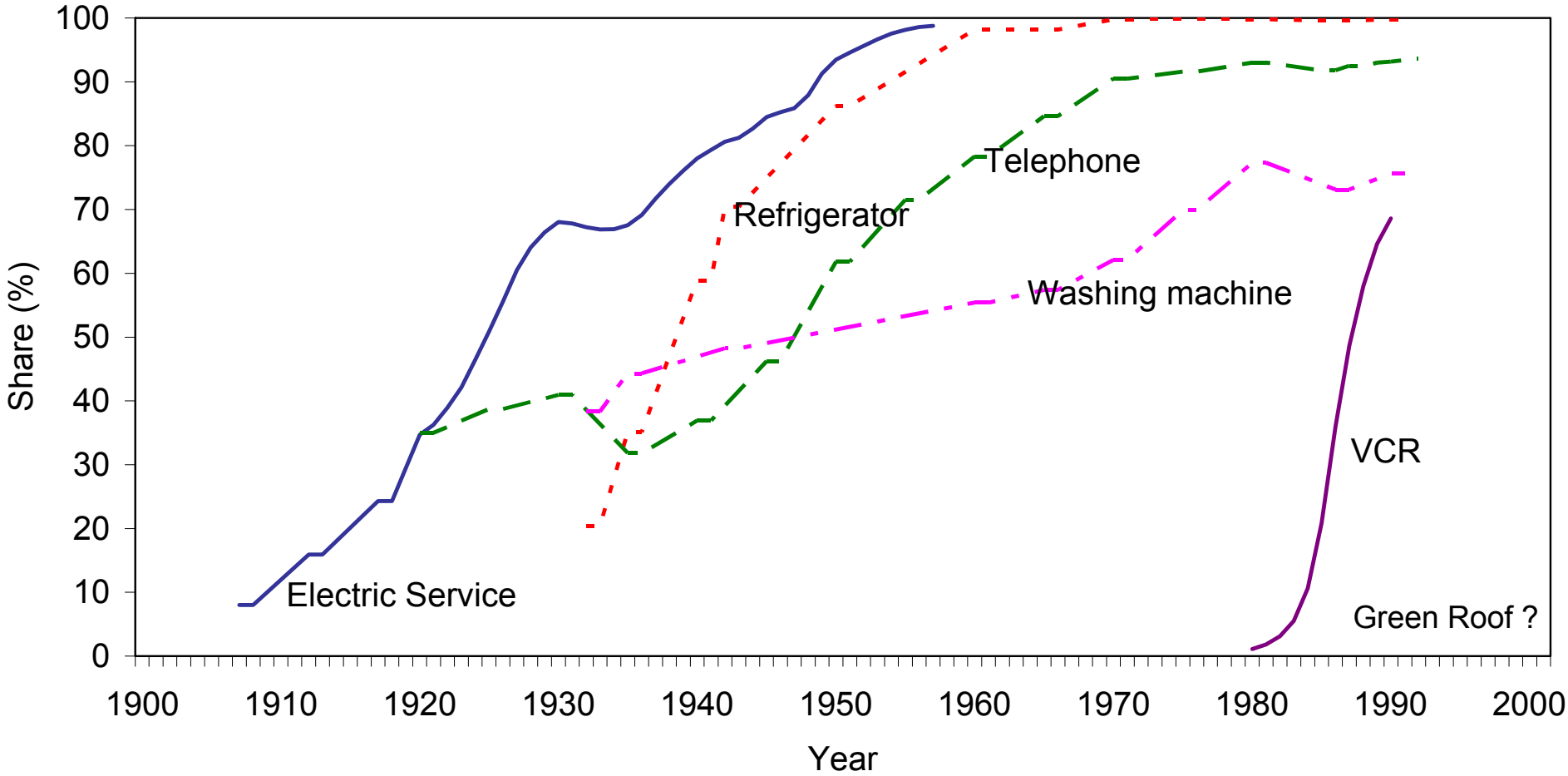
# Current State and Requirements for Increased Use

- Mature industry in Europe (20% of roofs are green in Germany)
- Expanding industry in North America (many vendors, specific building association, annual meeting)
- Multiple university research centers in US (Penn State, Michigan State, Southern Illinois)
- More research needed; directed at specific climate zones, type of built environments, and different market sectors
  - e.g. not at lot of work done in southern climates
- Expanded use will probably involve a combination of
  - Compulsory regulation
  - Financial incentives
  - Information transfer/education

# Diffusion of Technology *(Everett Rodgers)*




Innovators (2.5%) - venturesome, educated, multiple info sources, greater propensity to take risk
Early adopters (13.5%) - social leaders, popular, educated
Early majority (34%) - deliberate, many informal social contacts
Late majority (34%) - skeptical, traditional, lower socio-economic status
Laggards (16%) - neighbours and friends are main info sources, fear of debt

# U.S. diffusion of major inventions