Green Roofs and Water Resource Sustainability

Mark Mitchell, PhD
Greater Ohio Living Architecture (GOLA) Center of Excellence and
The Department of Biological and Environmental Sciences, Heidelberg University
Outline

• What is a green roof?

• Why are green roofs installed?
  – Ecosystem services provided by green roofs
  – Green roofs and stormwater
  – Green roofs and water quality
  – Economic benefits of green roofs, in particular related to stormwater control

• Policy and incentives
  – Successes and room for improvement
    • Green roof programs and incentives
    • Recommendations

• GOLA introduction and resources
What Is A Green Roof?

Mark Mitchell
Cincinnati Civic Garden Center, Cincinnati, OH
Two Major Types of Green Roofs

Intensive

Columbus Square, Columbus, OH

Greenroofs.com

Extensive

Green roof in Malmo, Sweden

Mark Mitchell
Why Green Roofs?

OSU’s Howlett Hall, Columbus, OH
Why Green Roofs?

Aesthetics
Why Green Roofs?

Aesthetics

Insulation and Passive Cooling

Vegetated Roof Layer Temperatures
(Example for a sunny afternoon; degrees F)

- Outside Air: 90°F
- Foliage: 96°F
- Stem Gap: 93°F
- Planting Medium: 86°F
- Drain Layer: 80°F
- Waterproofing/Protection Layer: 77°F
- Insulation (if necessary): 77°F
- Roof Deck: 73°F
- Ceiling: 72°F
- Interior: 72°F

- Solar radiation heat addition
- Reflected solar radiation
- Long-wave radiation heat transfer to sky/atmosphere
- Convection heat transfer with ambient air
- Mass heat transfer (evaporation)
- Conduction heat transfer through roof system
- Heat absorbed or released by high mass layers

Heat generated indoors by bodies, lights, computers, etc.
Energy Benefits- US EPA Case Study in KC, MO

This equates to a savings of $0.06 /ft²

And a savings of $1,800/year for a 30,000 ft² warehouse

Or a savings of $140/year for a 2,400 ft² average home
Urban Environment- USEPA Case Study in KC, MO

Table 1. Green roof calculator inputs

<table>
<thead>
<tr>
<th>Input</th>
<th>KCMO Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total surface area of green roofs in 2020</td>
<td>734,826 ft²</td>
</tr>
<tr>
<td>Building type</td>
<td>Existing office buildings</td>
</tr>
<tr>
<td>Growing media depth (2–11.5 inches)</td>
<td>4 (typical for the type of vegetation in the Kansas City area)</td>
</tr>
<tr>
<td>Leaf area index (LAI)</td>
<td>5 (typical for extensive green roofs)</td>
</tr>
<tr>
<td>Whether there is irrigation</td>
<td>No irrigation</td>
</tr>
<tr>
<td>Percent roof coverage</td>
<td>100%*</td>
</tr>
<tr>
<td>Albedo of existing roof</td>
<td>Dark (0.15)</td>
</tr>
</tbody>
</table>

* The user may choose to enter either total roof coverage or total green roof coverage. EPA entered 100 percent as the total known amount of green roof coverage. If EPA had used total roof area and estimated what percentage of that area was “green,” the average coverage for Kansas City’s green roofs would have been 60 percent of total roof area.

Table 4. Average sensible heat exchange to the urban environment for KCMO roofs

<table>
<thead>
<tr>
<th></th>
<th>Conventional Roof (W/m²)</th>
<th>Green Roof System (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual average</td>
<td>51.8</td>
<td>27.2</td>
</tr>
<tr>
<td>Summer average</td>
<td>92.7</td>
<td>33.4</td>
</tr>
<tr>
<td>Summer daily peak average</td>
<td>348.5</td>
<td>90.3</td>
</tr>
</tbody>
</table>

Sensible heat changes the temperature of the environment, latent heat is felt as humidity
US EPA. 2018. EPA 430-S-18-001
Why Green Roofs?

- Aesthetics
- Insulation and Passive Cooling
- Reduced Urban Heat Island
Why Green Roofs?

- Aesthetics
- Insulation and Passive Cooling
- Reduced Urban Heat Island
- Habitat
Why Green Roofs?

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- Health

Mercy West Hospital, Cincinnati, OH
Due to reductions in air pollutants, the EPA model estimates health care related savings of $35,000 to $80,000 per year for the region.

However, these estimates do not include NO\textsubscript{x} reduction benefits, which may be large but are difficult to track because NO\textsubscript{x} is a precursor to smog.

Table 6. Annual avoided air pollutants across the Lower Midwest AVERT region as a result of KCMO green roofs

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Total Avoided Air Pollutant Emissions in 2020 (Annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO\textsubscript{2}</td>
<td>2,690 lbs/year</td>
</tr>
<tr>
<td>NO\textsubscript{x}</td>
<td>1,800 lbs/year</td>
</tr>
<tr>
<td>PM\textsubscript{2.5}</td>
<td>90 lbs/year</td>
</tr>
<tr>
<td>CO\textsubscript{2}</td>
<td>1,150 tons/year</td>
</tr>
</tbody>
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Why Green Roofs?

Aesthetics

Insulation and Passive Cooling

Reduced Urban Heat Island

Habitat

Health

Stormwater
Columbus Discharge Locations
• Estimated overflow volume of 11.5 billion gallons of raw sewage combined with stormwater in Cincinnati (Project Groundwork)
• 4.5 billion gallons in Cleveland area (Project Clean Lake)
• Approximately 772 communities in the US that have combined sewer systems (US EPA)
Grey Infrastructure Approach

Stormwater runoff capture tunnel in Milwaukee, WI

www.prairie.com
Green Roofs and Water Quantity

Cincinnati Civic Garden Center Roof
Example rain event (12mm) from July

Buffam and Mitchell Unpublished Data

Most extensive green roofs will reduce stormwater flows on an annual basis by >50%

Green roofs also delay stormwater runoff

But flow dynamics depend on climate and green roof design
Green Roofs and Water Quantity

Cincinnati Civic Garden Center Roof
Example rain event (12mm) from July

Buffam and Mitchell Unpublished Data
GSA.gov 2011
Phosphorus Limits
Ecosystem Productivity

nationalgeographic.com
Green Roofs and Water Quality

Adapted from Wayne, Eckelman, and Zimmerman 2013. Environmental Sc. and Tech.
Green Roofs and Water Quality

Adapted from Wayne, Eckelman, and Zimmerman 2013. Environmental Sc. and Tech.
Green Roofs Frequently Act As Sources of Phosphorus

An Opportunity to Improve Their Design and Management
Why Green Roofs?

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- Habitat
- Health
- Stormwater

Combined Benefits from One Installation
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Combined Benefits from One Installation
Green Roof Economics

Benefits

Costs

NPV = Net Present Value

Rinaldi, Buffam et al. In Prep

Assumes a 40 year lifespan of the green roof and a 20 year lifespan of a conventional roof.

Model based in Cincinnati with CSO’s present.

Largest cost of green roof is related to installation but roof replacement costs are reduced.

Substantial benefits related to wastewater.

NPV of Life Cycle Cost over Green Roof Lifetime 2013USD

NPV = Net Present Value

Rinaldi, Buffam et al. In Prep
Green Roof Economics

Annual NPV for Green Roof and Conventional Roof
2013USD

NPV = Net Present Value

Rinaldi, Buffam et al. In Prep
Green Roof Economics

Note that the largest economic benefit of the green roof in this model is due to reductions of NO\textsubscript{x} and improved air quality.

This is a public benefit, but not always a benefit that will be realized by the property owner.

Policy and incentive programs can help monetize these benefits.

NPV = Net Present Value

Rinaldi, Buffam et al. In Prep
Policy and Incentives for Green Roofs

- Chicago: expedited permitting process, grants
- Tokyo: fines for non-green roofs
- Berlin: required for certain land uses
- Cleveland, Seattle, Portland, Philadelphia, and others: reduced stormwater fees
- Seattle: Biotope Area Factor
- Toronto: Most explicit and comprehensive building code

Recommendations for Ohio

- Clarify and market incentives if already present
- Look into initiation of a low-interest loan program
- Favor retrofits and passive systems
- Favor installations of green roofs with PV panels
- Mandates?
San Francisco approves green roof mandate

San Francisco has become the first city in the U.S. to approve such an obligation, which requires all new buildings to have at least 50% of their square footage covered by green roofs and/or green walls. The city's goal is to reduce the urban heat island effect and improve air quality.

September 19, 2016

In San Francisco, the green movement is gaining momentum. The city is leading the way in green building practices, with a new ordinance requiring all new buildings to have green roofs.

Often considered the most environmentally friendly building trend, green roofs are becoming increasingly popular in cities around the world. Green roofs provide a number of benefits, including improved energy efficiency, reduced stormwater runoff, and lower cooling costs.

The new legislation, which was passed unanimously by the City’s Supervisors earlier this week, sets a precedent for other cities in the United States to follow. By requiring new buildings to incorporate green roofs, San Francisco is taking a significant step towards a more sustainable future.

In this case, the ordinance is not only environmentally friendly, but also cost-effective. Green roofs can help reduce energy costs, improve air quality, and provide a healthy environment for people living and working in the city.

The city’s green movement is not limited to buildings. San Francisco is also home to a number of green spaces, including parks and gardens, which provide a much-needed break from the urban environment.

Overall, San Francisco’s new green roof mandate is a positive step towards creating a more sustainable and healthy city. As the city’s population continues to grow, it is important to consider the impact of our buildings on the environment and to find ways to reduce our carbon footprint.

Denver’s Revised Green Roof Ordinance Takes Root

BY RACHAEL FORREST

The new legislation, which was passed unanimously by the City’s Supervisors earlier this week, sets a precedent for other cities in the United States to follow. By requiring new buildings to incorporate green roofs, San Francisco is taking a significant step towards a more sustainable future.

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Portland’s New Ecoroof Requirement: New Design and Maintenance Strategies

POSTED ON SEPTEMBER 10, 2018 AT 2:46 PM.
WRITTEN BY COMMUNICATIONS CHAIR

BY JACKIE SNOW

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Green Roofs Are A Single Tool In Our Stormwater Reduction Toolbox

New York City Green Infrastructure Plan
Greater Ohio Living Architecture Center

Kent State University
University of Cincinnati
Heidelberg University

www.GOLAcenter.org
Living Architecture

‘study and practice of integrating living systems into buildings to make cities more livable.’

Education and Outreach

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- Policy and Code
- Incentive
- Design
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<tbody>
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<td>Virginia Russell</td>
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<td>Director of Pedagogy</td>
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<tr>
<td>Dr. Ishi Buffam</td>
<td>U. Cincinnati</td>
<td>Director of Research</td>
</tr>
<tr>
<td>Dr. Mark Mitchell</td>
<td>Heidelberg U.</td>
<td>Director of Professional Outreach</td>
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</table>

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- Diane Davis-Sikora, Associate Professor: Architecture, Studio Design
- Dr. Adil Sharag-Eldin, Associate Professor: Architecture, Energy and Climate
- Greg Stroh, Associate Professor: Architecture, Studio Design/Fabrication
- Dr. Rui Lui, Assistant Professor: Architecture, Structural Design
- Dr. Christie Bahlai, Assistant Professor: Biology, Ecology and Data Science
- Dr. Anne Jefferson, Associate Professor: Urban Hydrology
- John Gerrath, Adjunct Professor: Biology, Plant Ecology

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- Dr. Theresa Culley, Professor: Biological Sciences, Plant Eco and Genetics
- Dr. Pravin Bhiwapurkar, Assistant Professor: Architecture, Urban Climate & Building Sci.
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- Barry Kew, ASLA, Associate Professor: Vegetated Roofs/Walls Performance Eval.

*Heidelberg University*

- Dr. Amy Berger, Professor: Hydrology, Soils
- Dr. Laura Johnson, Director National Ctr for Water Quality Research: Water Quality
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members
Re-imagining Living Architecture: Water Management and Beyond

A Seminar Presented by:

Green Roofs for Healthy Cities & Greater Ohio Living Architecture Center

When: May 21st, 2019
Where: Cleveland Urban Design Collaborative
1309 Euclid Ave. Suite 200, Cleveland, OH
Questions