GREEN CITIES IN THE WORLD

Editors
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IN THE WORLD

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The lush, un-irrigated greenroof on the sixth and seventh floors of this New Jersey shore Diamond Beach Condos complex provides peaceful enjoyment for all residents and private gardens for the penthouse residents. Source: Greenroofs.com; Photo Courtesy of Roofmeadow. landscape, health, green urban markets.

*Vertical garden.
Zaragoza. Spain.
Source: Joaquin Sicilia.*

PREFACE

The first World Green Infrastructure Network (WGIN) book project is complete. The editors have selected the main facets of Green Infrastructure from around the world. The resulting publication therefore represents "Green Infrastructure (GI) in a Nutshell." There are many additional ideas worthy of being printed but as the first compendium from WGIN, we present a wide range of green infrastructure development opportunities and projects.

The idea of green building is quite simple. It is possible nearly everywhere and provides benefits throughout the process from product manufacturing through to construction operation and repurposing.

Since we started the World Green Infrastructure Network in 2007, there have been questions from outside. Is it really necessary to focus on such a small part of city development? We are convinced that green roofs and walls have a great future and are a huge untapped spatial resource with many measurable opportunities to support healthier urban environments.

One aim of WGIN is to support new green roof and GI initiatives around the globe. It is interesting that in nearly all countries projects have now been completed and there is an increasing interest to learn more about the effects of such technology on building owners and the public in cities.

Forming national green roof associations in all the countries will take more time. To convince local people about the benefits of using this technology, you need local knowledge and examples as well as international evidence that such technology is successful.

Over the past few years, worldwide interest has increased from single iconic roof garden projects, to today's more integrated concepts carried out at the level of buildings or neighborhoods. When our organization was founded in 2007, the term "green infrastructure" was seldom used. Now it has become integrated into programs at the European Union level. It is also now part of strategies to enhance biodiversity in cities. The cities of Europe are requested to set up biodiversity strategies and green roofs can link and connect the ground level vegetation.

The success of WGIN is due to the work of many people in this non-governmental and not-for-profit organization. The next task of WGIN is to work as an international organization to spread the idea of GI to organizations throughout the world.

WGIN presents the following arguments for more green infrastructure in cities:

- Many positive effects in cities are connected to greenery. One decorative tree is not enough.

A technical building in a back yard area.
Source: M. Köhler.

- We have to use all spatial resources to provide massive cover of vegetation.

- A lack of greenery is a problem in cities of all sizes due to limited space at the ground level.

- Billions of meters of roofs and walls are a great spatial resource for vegetation projects.

- Indoor greening is a developing field. It helps people to perform their work better inside buildings, regulates the room-level climate, and saves air conditioning costs.

- Green infrastructure (GI) offers a toolbox for urban areas within the categories of roofs, façades, and indoor greening, and addresses the important criteria of plant selection, rainwater management and climatic regulation.GI planners have to play with such a tool box. These categories provide opportunities to explore various types of vegetation, from local and native plants to ornamental and even edible species.

- GI is an optimistic tool, possible in all climates of the world and in cities of all sizes.

- GI investments.

- Create many jobs.

- GI is one way to construct additional green spaces beyond typical parks and traditional green spaces in cities. GI on buildings can link these traditional green areas, encouraging green dissemination into all parts of cities as a biodiversity strategy.

- GI is a critical component of how we should construct cities of the future.

- Vegetation is multifunctional, working like a biological accumulator due to the main principle of evapotranspiration and its benefits. These aspects can be calculated, counted and described as benefits to citizens.

- GI counts, the slightly higher first investments of cities provide a significant return on investment over the whole lifespan of buildings. Examples can be found here in this book.

- GI needs norms and guidelines. Within our group of members, many detailed regulations have been written, which help to construct new projects and form long-lasting solutions.

- Many of these authors were present at the WGIN conference in Nantes, France in September of 2013. Some authors from this conference were invited to deliver their summarized views on the various GI-related aspects of this book and highlight the most relevant papers on GI from their perspective. We cannot refer to all published, peer-reviewed titles regarding GI, but in this summarized form, it is possible to find details about each academic question in a targeted publication. There are also links to the cost-benefit calculations of this technology. Spending money in GI is good for nature and for the economy. It was our goal to make the chapters as compact as possible but provide all links needed to delve deeper into the aspects discussed.

The second part of this book contains some descriptions of national contact people and state-of-the-art technologies being used in various countries and by various associations. The number of organizations is continuously growing. The more partners in this network, the higher the output and benefits for all members can be.

GI is a professional tool for implementing nature on buildings. Here, one has information about many norms and guidelines. If these are followed well, GI offers benefits for the full lifespan of buildings. We hope you enjoy the many new ideas in this book!

Berlin, April 2014

Manfred Köhler
President
World Green Infrastructure Network

The renovation of the LEED-NC Gold certified Haworth Corporate Headquarters in Holland, Michigan includes a greenroof whose west end slopes down six stories to grade. Source: Greenroofs.com; Photo Courtesy of LiveRoof. landscape, health.

FOREWORD

The migration movement from rural to urban areas will concentrate humanity over the next two decades to where 80 percent of the population will live in metropolitan areas. There are many arguments regarding this phenomenon, and the challenge is whether the biosphere will be able to satisfy all of the potential demand on services, food consumption, the environment and human health.

The analysis of the green cities frontier should be an important source of information for the citizens and urban policy makers to identify the priority problems and their solutions. Information from international experiences may direct the measures and programs of other cities facing similar problems. Thus, the cooperation and exchange of knowledge through related national and international organizations (WGIN, IGRA) and the use of social networks with ICT are useful instruments for new urban designs.

In addition, local administrations and private institutions have to consider that adopting green building practices may reduce expenditures in energy, water, and waste processing. The scientific philosopher, Bertrand Russell, considered that changes that originate innovation have a scientific essence. However, while change is inevitable in a dynamic society, progress may be problematic. Thus, our megalopolises of glass, steel and mortar may provide a short term solution to housing demands for a number of people. However, the human agglomeration, with external dependency, environmental damage and isolation from nature, does not increase net value added, with problems in health, stress and other unwanted elements.

Green activities, trying to improve the conditions of our environment within the new framework, may be the cornerstone of the smart cities revolution. But revolutionary movements need radical changes in techniques, equipment and the mental status quo. Therefore, sociopolitical forces have to move and allow to all the players to participate and share in the responsibility of the performance of the living city.

With this mentioned situation in mind, WGIN and PRONATUR considered the opportunity to publish this book , with multidimensional topics analyzed by international experts, discussing a very broad range of scenarios, and covering the information of 25 national areas from all continents.

Under these guidelines we have organized the publication into areas socioeconomics and policy, environment, architecture and technical and national stories.

The green national organization section provides us with information about global green infrastructure practices through the profiles of 25 national stories in 360 pages.

A selected group of international experts participated in the technical and socioeconomics areas. Their academic and professional affiliations (architects, engineers, botanists, biologists, economists and others) are very heterogeneous, as is the case in the real world, but they share the common goal of improving our urban environment in a sustainable way.

The book tries to offer an international reference on some of the critical points of urban greening. The expected audience includes professionals, academics, practitioners, NGOs, and individual people interested in green urban matters. Our hope is that readers will find useful materials and opinions for their daily work and entertainment.

Madrid, April 2014

Julian Briz and Isabel de Felipe
Polytechnic University Madrid. Pronatur

Roof gardening.
Source: M. Köhler.

ACKNOWLEDGEMENTS

Greening cities is an emerging movement internationally. Therefore, this book had to encompass a global horizon and required the collaboration of experts and institutions from all over.

Publications are the results of joint efforts of authors, editors, publishers and collaborators, trying to satisfy the intensified demand of society. In our case, there are additional factors that are especially attractive, such as the multitude of topics and authors from all over the world, that give this publication additional value.

WGIN and **PRONATUR** have been the core associations that have promoted the idea of having a book about the problematic nature of greening cities in our world and have coordinated human and economic resources from research centers and universities, especially Polytechnic University of Madrid and Hochschule Neubrandenburg.

For individual recognition, there was a preeminent role of **Kelly Ksiazek**, who contributed with her special efforts and knowledge, to improve the English edition and style correction. The researcher **Rocío Viniegra** from UPM has collaborated in the composition and edition of the text.

A very special place in this acknowledgement goes to **Greenroofs.com** and personally **Linda Velazquez**, for the continued advice and supply of excellent photography included in the text.

We also thank the hidden collaborators from a number of institutions (universities, research centers, firms, local administrations, NGOs) that have provided information, photographs and other facilities to the authors and editors. Their collaborations will continue with the promotion and publicity of the book.

The publisher, **Editorial Agrícola** has provided their experience and effort in order to accomplish their high quality professional work in good time.

Last but not least, thank you to the expert authors for their time-consuming efforts, which contribute to a high-quality understanding of urban greening in our society.

Madrid and Berlin, April 2014

EDITORS
Julian Briz, Manfred Köhler, *and* ***Isabel de Felipe***

ETSI. Agrónomos.
UPM. MADRID
Source:
I. de Felipe.

ECONOMY, SOCIOLOGY AND POLICY SCENARIOS

Caixa Forum. Madrid.
Source: I. de Felipe.

CHAPTER 1

DEVELOPING THE GREEN ROOF AND WALL INDUSTRY IN NORTH AMERICA FOR GREENER, HEALTHIER CITIES: CHALLENGES, OPPORTUNITIES AND LESSONS LEARNED

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GRP. Honorary ASLA.
Founder and president, Green Roofs for Healthy Cities - North America Inc.
Founder, Green Infrastructure Ontario.
Co-founder, World Green Infrastructure Network

1. INTRODUCTION

The people who live in the City of Toronto, Canada are tremendously fortunate because Toronto has beautiful Lake Ontario at its southern edge and hundreds of gorgeous river valleys and ravines that stretch 30 to 40 miles northward like undulating ribbons of green. As a child I often played in these ribbons of green catching frogs, picking apples, climbing trees and occasionally spotting a beaver, great blue heron or even a white tailed deer. Many species of migratory birds use the river valleys to stop and rest on their spring migration over this fast growing city of 2.5 million people, as they head northward where the insects are plentiful.

My early love for the valleys and ravines has translated into action. While in my early twenties, I started a small environmental group called Friends of The Don East York. We lobbied to stop inappropriate development in the Don River Valley and supported tree planting and the redevelopment of wetlands, which are so important for watershed ecosystem health. This effort was part of a larger watershed regeneration movement in Ontario that started in the 1990's and continues today. It is focused on the preserving the health of the entire watershed, crossing political boundaries to try to coordinate land purchase for conservation, public education, restoration and protection activities. (www.trca.on.ca)

These pre-existing natural areas are like a green baseline for the City of Toronto, and combined with our parks system and the shoreline of Lake Ontario, form an important green infrastructure foundation. This foundation of green spaces supports ongoing efforts to green the city, simultaneously making it more economically, socially and environmentally sustainable. Without this foundation of green spaces and places that provide daily opportunities for people to experience our deeply rooted, biophilic connection to the natural world, it would be much more difficult to generate the political will to make the necessary policies in support of a greener city. Without an attachment and appreciation of nature in the city, it would be much harder to move our efforts to green the city beyond the valleys to the walls and rooftops of our buildings.

Green roofs first came to my attention in 1996, at a conference on financing municipal environmental management I had organized as an independent policy consultant working in the field of sustainable community development.

Drew School, San Francisco, CA 2013 Award of Excellence Source: ROMA Design Group. Joe Fletcher.

Dr. Brad Bass, then a scientist at Environment Canada asked me if I had heard of green roofs over lunch, and soon the two of us joined forces with local architect Monica Kuhn and began working together to try to develop the green roof industry, which was already well established in Europe, particularly Germany at that time. I was intrigued by green roofs because they had so much potential for implementation, and could provide so many diverse public and private benefits by taking advantage of the largely wasted roofs in our cities. Green roofs also have a unique contribution to make, in moving the building industry towards the development of green, high performance and restorative buildings – the ultimate goal of the green building movement. Restorative or regenerative buildings go beyond being less damaging to actually helping us to heal the damage we have done to the planet. Restorative buildings produce more renewable energy than they use, they improve habitat, clean the air, are self sufficient in water use and treatment, are beautiful and healthy for occupants and even produce food (Living Building Challenge, www.ilbi.org).

In 1996, neither Brad, Monica nor I had any idea how our initial efforts would shape our careers for the next fifteen years and support the rise of the green roof and wall industry in North America which implemented an estimated 25 million square feet of green roofs on buildings in 2012 and over 100 million square feet since 2004, the year we began collecting statistics.

In 2012, we adopted the inspirational goal for the North American green roof industry to install and maintain another 1 billion square feet of green roofs by 2022, a figure that is well within our capability. The rapid growth of 'living architecture' - the green roof and green wall industry - came about largely due to strategic decisions we made more than a decade ago and through the hard work and dedication of hundreds of professionals. Our success to date has meant overcoming many challenges, like having little technical performance data, public awareness or professional training. We have been able to take advantage of many policy opportunities and important drivers, such as the need to manage storm water more effectively. We have also tapped into humanity's basic, most fundamental need and desire for natural environments; something as basic as water, food and shelter, but all too often forgotten during the rapid development and redevelopment of our cities.

THE PUBLIC BENEFITS OF LIVING ARCHITECTURE SYSTEMS

URBAN HEAT ISLAND MITIGATION RESULTING IN:	CARBON SEQUESTRATION:
Energy savings in buildings and resulting greenhouse gas emission reductions	Plants and growing media can sequester carbon generating carbon credits
Less smog formation	
Reduction in particulate matter in the air	EMPLOYMENT FROM MANUFACTURE, DESIGN, INSTALLATION, MAINTENANCE AND NEW USES RESULTING IN:
More livable environment for citizens and less heat related stress	Fewer social problems
Water conservation	Additional recreational opportunities
Reduction in associated heath care costs from improving air quality and reducing heat	
Contribution to savings on power plants and transmission infrastructure	INCREASE IN PROPERTY VALUES WITH A CORRESPONDING RETURN IN PROPERTY TAXES TO THE CITY

IMPROVEMENTS IN ONSITE STORMWATER MANAGEMENT RESULTING IN:	NOISE ATTENUATION AND SOUND IMPROVEMENT RESULTING IN:
Reduction in the frequency of combined sewer overflow events	Less noise entering buildings which may result in increased property values
Increase in life expectancy of pipes and other grey infrastructure	Biophilically satisfying noises – like wind rushing through grass
Reduction in costs of erosion control	
Reduction in frequency of flooding	SHADING RESULTING IN:
Improved water quality	Fewer sun related health issues
Receiving waters become more fishable, swimmable, drinkable	Cooler more enjoyable streets, parking lots, subway platforms

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AESTHETIC/BIOPHILIC IMPROVEMENTS RESULTING IN:	IMPROVEMENTS TO BUILDING ENVELOPE LONGEVITY RESULTING IN:
Healthier and more productive citizens	Reduction in landfill waste
Less crime and associated policing, judicial and incarceration related expenses	Replacement cost savings on public buildings
Improved economic activity	
More community cohesion	**IMPROVED BIODIVERSITY RESULTING IN:**
Increase in walking, cycling, gardening and running	Educational/Urban nature experiences
Beautifying unattractive building features	Carbon sequestration by protecting migratory birds which support boreal forest growth
Opportunities for artistic expression	Pollination by insects, particularly bees
Reduced patient care costs in health facilities	Beauty and improved recreation opportunities, such as bird watching

URBAN FOOD PRODUCTION RESULTING IN:	INCORPORATION OF GREEN PRODUCTS AND SYSTEMS RESULTING IN:
Greater food security	Improved markets for recycling plastics
Better food quality	Improved markets for compost and recycled aggregates
Increased employment	Lower emergy in overall system
Reduction in transportation of food with associated air pollution, greenhouse gases, traffic, etc	Improved conservation of water resources
Community self-reliance and improved cohesion	

Source: The Rise of Living Architecture, 2013. (See www.greeninfrastructurestore.com)

2. LESSONS LEARNED IN NORTH AMERICA FROM DEVELOPING THE GREEN ROOF AND WALL INDUSTRY

In 1998, Brad and I applied for funding from Canada Mortgage and Housing Corporation to conduct a study on barriers and opportunities associated with green roof technology. With Monica Kuhn, a German speaking local architect, and Chris Callaghan, a local researcher, we produced what was essentially a blue print for developing the industry in North America – "Green Backs from Green Roofs: Forging a New Industry In Canada". This report, which utilized data on benefits from Germany translated by Monica and interviews with a few

Vancouver Convention Centre, Vancouver, BC 2010 Award of Excellence Source: PWL Partnership Landscape Architects Inc.

leading companies working in this field and the design community, really laid the ground work for Green Roofs for Healthy Cities, a coalition of companies I brought together to develop a demonstration project in Toronto. This work ultimately led to the establishment of the non-profit industry association in 2004 to further the development of the industry. All along, the key to our success was based on the active engagement of four different types of professionals – scientists, policy makers, designers and manufacturers – like four legs on a stool. Some of the key principles involved and programs and resources we have developed in support of the industry are described in detail below and will hopefully be of use to people who are interested in advancing living architecture in their own countries.

Committing to the Science of Performance

This goal of engaging science and scientists has been realized in many of the programs and activities of Green Roofs for Healthy Cities. Early on, we recognized that the industry needed impartial, objective scientific information on the performance of green roof systems in order to allay fears of failure and verify the performance claims of these systems. Our early partnership with Canada's Institute for Research in Construction (IRC) on green roof demonstration projects at Toronto City Hall and the East view Community Center not only produced important data on energy savings and stormwater but also spurred the development of dedicated green roof research in educational institutions such as Penn State University, Michigan State University, the Ottawa Campus of IRC and the British Columbia Institute of Technology. Dr. Brad Bass, Dr. Karen Liu, Dr. Maureen Connelly, and Marie-Anne Boivin are several of the early green roof research pioneers in Canada. In the U.S. there was Dr. Brad Rowe, Dr. David Beattie, and Tom Liptan. Currently, there are more than 100 academic institutions currently undertaking research on all aspects of green roofs, from individual plant species survival to how to reduce the urban heat island effect. More recently, we have seen a healthy increase in green wall research on water and energy performance. We recently completed a collective research project in partnership with GRHC corporate members such as greenscreen, Carl Stahl and Jakob who supply green facade technologies, those that support climbing vines growing away from the building envelope.

Our support for scientific research has also involved working with various stakeholders to develop a research protocol focused on biodiversity research. At our annual conference, *CitiesAlive*, we have a dedicated series of speakers on the latest research developments whose work must go through a peer review process. Technical paper summaries are provided online through our "Green Roofs Tree of Knowledge" searchable database and the full papers can be purchased on CD while more recently the entire collection of conference papers is now available for purchase on a single memory key. (see www.greeninfrastructurestore.com)

As a result of research on large scale benefits such as reductions in flooding and reducing the urban heat island effect, my colleague Hitesh Doshi and I were able to put together a table which lists how many public benefits of green roof installation can translate into economic benefits. This table is part of a paper that is designed to help policy makers and designer understand the potential public benefits that may result from the widespread installation of green roofs. The numbers will vary from jurisdiction to jurisdiction but can be used as a guide to perform a basic cost-benefit study of green roof policy.

Halifax Seaport Farmers' Market, Halifax, Nova Scotia 2012 Award of Excellence Source: Lydon Lynch Architects Ltd.

ESTIMATES OF PUBLIC BENEFITS FROM GREEN ROOF INSTALLATION CDN $/ SQUARE METER

BENEFIT	VALUE RANGES $/m²	STUDIES THAT CONSIDERED IT
Stormwater infrastructure cost reduction due to volume reduction – Capital	$0.3 to $45.9	Toronto, Portland, Tomalty, Clarke
Stormwater infrastructure cost reduction due to volume reduction – Operating and Maintenance	$0.358	Portland
Combined sewer overflow reduction in storage – Capital	$0.9	Toronto
CSO – environmental impact – annual	$0.015	Toronto
Reduction of pollutants through capture by vegetation – annual	$0.052 to $1.695	Toronto, Portland, Tomalty, Clarke
Air Quality (Nitrous Oxide componds) (EPA Study)	$.000074 to .055	GSA
Air Quality (Particulate Matter PM10)	$0.000106	GSA
Air Quality (Sulfur-oxygen compounds)	$0.000000185	GSA
Building Energy – Reduction in energy infrastructure – Capital	$1.378	Toronto
UHI – reduction in energy demand and infrastructure – Capital	$1.601	Toronto
Reduction in GHG due to reduction in energy demand – annual	$0.002 to $0.215	Toronto, Portland, Tomalty, Clarke
Creation of habitat – Capital	$6.808	Portland
Habitat Creation (Australia's BushBroker Scheme which replaces vegetation on denuded land for habitat) - Capital	0.039 - 0.1356	GSA Report
Habitat Creation (US Biodiversity Banking System) - Capital	$0.0381	GSA Report
Job creation – job creation estimates are provided as jobs/m² of green roof	0.6 to 1.1 person years of jobs per 1000 m² of roofing (Toronto) or 4.2 jobs per 1000 m² of installed roofing (Washington DC)	Toronto, American Rivers (Washington DC)
Maintenance (Extensive)	0.124 person hours/square meter/visit (2 per year)	GSA
Maintenance (Intensive)	139 person hours/square meter/visit (4 per year)	GSA
Flooding Avoided Costs (Figures are very site specific)	$9000 per 4,046 square meters of floodplain for the 100 year event to $21,000 per 4046 square meters for the 2 year storm event.	ASLA et al.

Source: H. Doshi and S. Peck, 2013, "Methods for Estimating Economic Public Benefits from Regional Implementation of Green Roof Technology" (World Green Infrastructure Congress, Nantes, France).

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Source: (See www.livingarchitecturemonitor.com)

Kauffman Center for the Performing Arts, Kansas City, MO. 2013 Award of Excellence. Source: Jeffrey L. Bruce & Co.

In our free, quarterly digital magazine, the *Living Architecture Monitor™*, we publish exceptional research projects online and keep track of research published in various academic journals. In 2013, GRHC launched the peer-reviewed *Journal of Living Architecture* embedded in the *Monitor* which features several of the very best papers in the field of living architecture research each quarter. Under the leadership of Jennifer Foden Wilson, this new publication will help to integrate scientific findings into industry practice and provide an opportunity to highlight the best work in this emerging field.

There is much work that needs to be completed in the field of green roof and wall performance, and we are working on a project to develop standardized metrics of performance and test methods for generic green roof and wall systems that recognizes the important differences in weather and climate in the different regions across North America. *The Living Architecture Performance Tool* will take several years to develop but holds promise to inform voluntary green rating systems like the United States Green Building Council's (USGBC) LEED programs, Sustainable Sites and the Living Building Challenge. Clear performance metrics that are regionally responsive and comprehensive will also support integrated, multi-benefit analysis and design practice; facilitate product performance testing; support policy development by providing a reference standard for incentives and regulations; and identify major research gaps in terms of regional performance.

Developing Policy Support

Experience in Europe, particularly Germany demonstrates that there a many public benefits (in addition to private benefits) which stem from green roof and wall implementation. Furthermore, the green roof industry enjoyed significant growth when local governments established financial incentives and in some cases requirements for green roof construction in new and existing buildings. In North America, our initial focus was to work with local governments to organize and finance one day, local market development symposia designed to explore barriers and opportunities to develop policies that support the development of local industry. Over the past decade we've held more than 30 of these events, and we have seen the adoption of green roof incentives and policies in a number of important markets. In addition, many jurisdictions have adopted the USGBC's LEED New Development voluntary green building standard, which supports the use of green roofs to obtain or contribute to attaining credits.

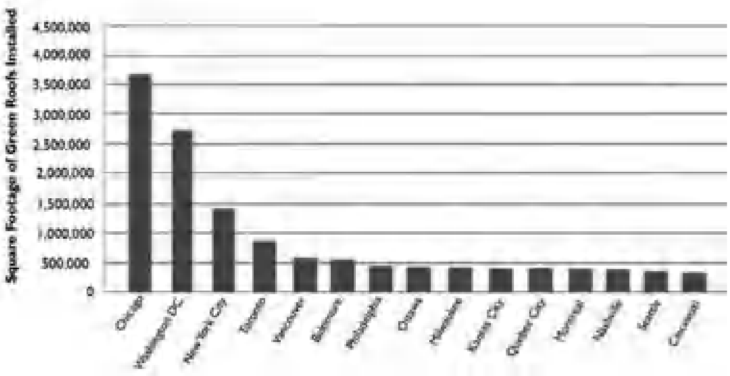
Dedicated North American Green Roof and Wall Policies, 2013

Each year, at our annual *CitiesAlive* conference, awards and trade show we have an award that is given to a government official or a political leader to recognize their support of green roof policy. These awards are promoted online and in our *Living Architecture Monitor* magazine and have helped us secure the political support needed to move policy forward in several markets. In our Annual *Green Roof Market Survey*, we calculate the number of square feet of green roofs installed each year, per metropolitan region, and have encouraged a competition between cities for the greatest number each year (www.greenroofs.org. See Resources). The chart on the next page provides a list of the top 15 jurisdictions based on the square footage of green roofs reported installed by GRHC corporate members from 2004 to 2011.

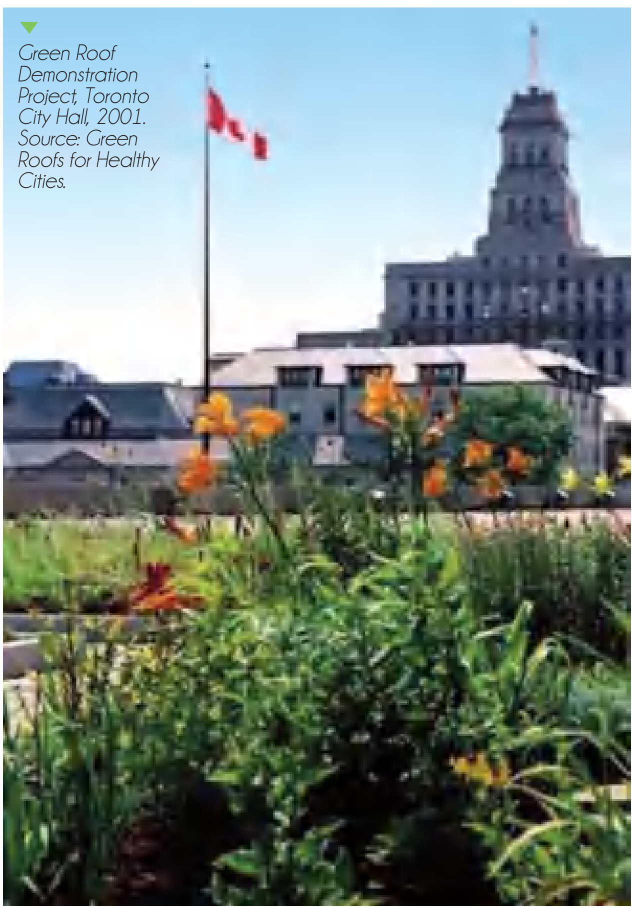
CITY/COUNTRY/STATE	NAME OF POLICY/INCENTIVE	YEAR IMPLEMENTED
King County, WA	Impervious Surface Cost Share & Credit Program	2004
Portland, OR	Ecoroof Incentive	2005
Minneapolis, MN	Stormwater Utility Fee Credit	2005
Chicago, IL	Green Permit Program	2006
Portland, OR	Clean River Rewards	2006
Port Coquitlam, BC	Green Roof Regulation	2006
Washington, DC	Green Roof Rebate Program	2007
Philadelphia, PA	Green Roof Tax Credits	2007
Seattle, WA	Green Factor	2007
Richmond, BC	Green Roof Bylaw 8385	2008
Anne Arundel County, MD	Stormwater Management Tax Credit	2008
New York State	Green Building Construction Act	2009
Toronto, ON	Green Roof Bylaw & Eco-Roof Incentive	2009
Bloomington, IN	Unified Development Ordinance	2009
State of Ohio	EPA Green Roof Loan Program	2009
Milwaukee, WI	MSD Regional Green Roof Initiative	2010
Onondaga County, NY	Green Improvement Fund	2010
State of Wisconsin	Vegetated Roof System Guidelines	2010
Devens, MA	Policy for the Constructions of Green Roofs	2011
Austin, TX	Green Roof Density Bonus	2011
Richmond, VA	Ordinance 2012-201-199	2012
Prince George´s County, MD	Rain Check Rebate Program	2013
Nashville, TN	Green Roof Rebate	2013

Source: Green Roofs for Healthy Cities (www.greenroofs.org)

SQUARE FEET OF GREEN ROOFS INSTALLED BY GRHC CORPORATE MEMBERS BY METRO REGION, 2004-2011



Source: Green Roofs for Healthy Cities, 2012



Green Roof Demonstration Project, Toronto City Hall, 2001. Source: Green Roofs for Healthy Cities.

In addition to these efforts, we have a series of dedicated policy presentations at our conference each year, selected by our Policy Committee, and have recently identified individuals as Green Roof Ambassadors who are working to promote green roof and wall policies in their local and regional jurisdictions with technical assistance and training from GRHC.

We have also provided policy making articles to professional journals and have developed a half day policy training course. In 2013, Professor Hitesh Doshi, Ryerson University and I surveyed the research and developed a method to estimate the public benefits associated with public green roof investments, which can be tailored to individual communities. If a government invests $10 million in green roof incentives, the method can be used to estimate a wide range of public benefits that will result from increased green roof development. This paper is available for free online at the www.livingarchitecturemonitor.com, Summer 2013 issue.

3. TORONTO GREEN ROOF BY-LAW CASE STUDY

In Toronto, we started working on green roof policy development in 1999 with a focus on developing a *Green Roof Research and Demonstration Project* on a small portion (10,000 sf) of the 70,000 square foot City Hall Podium Roof. We worked closely with scientists, bureaucrats, industry professionals and designers to develop the market. This demonstration project led to a number of tours, generated technical performance data, helped educate the general public, political leaders and the design community. Around the same time, the City of Chicago, under the leadership of Mayor Richard Daley, was developing a green roof demonstration project on its City Hall building located in downtown Chicago. Both Chicago and Toronto have since been leading cities in their support of green roofs. Both Chicago and Toronto led the market by requiring their own buildings to

Green Roof Demonstration Project, Chicago City Hall, 2001. Source: Courtesy of David Yocca, Conservation Design Forum.

implement green roofs as well as the many agencies, boards and commissions under its control.

The City of Toronto removed the demonstration project and built a full scale green roof on the Podium Deck at City Hall which opened in 2008. The City of Toronto hired Ryerson University to do an analysis of the benefits of widespread green roof implementation and struck a task force to develop building standards, a power granted to the City under the City of Toronto Act.

Under the leadership of Mayor David Miller and Deputy Mayor Joe Pantalone, the City of Toronto adopted the Green Roof By-law in 2009. The by-law consists of a requirement for new buildings over a certain floor area to include a green roof in a portion of the 'green roofable area' on their buildings, and describes the construction standard by which all green roofs in the City must be built. If new building owners want to opt out, then they must pay a fee of $200 CDN per square meter which is used to provide funds to existing building owners as an incentive to develop green roofs. The green roof policy and subsequent building boom have resulted in more than 2.5 million square feet of additional green roof space permitted in the City, the equivalent of two large city parks. Toronto is the first major city in North America with mandatory green roof requirements and a construction standard. Other jurisdictions have adapted these policies to meet their specific needs. (www.toronto.ca – search green roofs).

Full Scale, Accessible Toronto City Hall Green Roof. Source: I. de Felipe.

Given that there are a number of very tangible benefits that are available to building owners from green roof implementation, and that the by-law was implemented through a process of engagement and consultation with owners and industry representatives, it has been widely accepted, with very few opting to buy out of the requirement.

THE PRIVATE BENEFITS OF LIVING ARCHITECTURE

Energy savings due to reduced demand for heating and cooling from evapo-transpiration, thermal mass transfer, shading and insulation
Energy savings from shading and blocking the wind
Energy savings from pre-cooling air conditioning unit intake air
Energy savings from reducing the need to exchange indoor air
Carbon credits from associated energy savings
Savings associated with longevity increases to waterproofing and building envelopes
Improved indoor air quality resulting in improved occupant health and performance
Improved property values related to better visual amenity, accessible amenities and noise attenuation
Improved patient recovery in hospitals
Improved academic performance in schools
Marketing and promotional opportunities
Integration with the site for better overall stormwater management and reuse
Improved public relations/community relations and potentially faster project approval times
Improved rentability, saleability of properties and units
Contributes to reaching USGBC and CAGBC LEED credits
Contributes to meeting the Living Building Challenge 2.0 and Sustainable Sites ™
Access to public incentives and/or enhanced ability to meet regulations such as stormwater management
Integration with other building systems, such as mechanical systems and solar photo voltaic panels for better energy efficiency and generation
Potential to generate direct revenue for sale or lease of roof spaces, and from new uses such as urban agriculture production
Biophilic related benefits resulting in reduced absenteeism, improved staff retention, and better job performance

Source: Rise of Living Architecture, 2013. See www.greeninfrastructurestore.com

In 2007, with support from one of our corporate members, Tremco, we hired the Athena Institute to develop a life cycle cost-benefit tool called *The GreenSave Calculator*, which enables the user to compare the costs and benefits of a green roof project with two other types of roofs. Using life-cycle allows long term benefits such as energy savings and the longevity of the waterproofing to factor into the analysis more effectively. For clients that are interested in long term building performance, green roofs are a good investment. In 2011, the federal government agency, General Services Administration, (GSA) which owns or leases over 400,000 buildings across the United States, hired an engineering firm named ARUP to conduct a detailed life cycle cost benefit analysis of three different sized green roofs. The results of this study are contained in the table on the next page.

Notice the importance of the economies of scale as the size of the green roof increases so does the economic benefit relative to a black roof. The internal rate of return on the 50,000 square foot green roof project was 5.9 percent. Community net present value associated with benefits such as the urban heat island effect, air quality and biodiversity were estimated to by more than $30 per square foot over the life of the project.

4. GREEN INFRASTRUCTURE DECLARATION

Our work to develop the green roof industry and then later, the green wall industry, led us inevitably to the conclusion that policy development which is truly effective needs to reposition living, green technology systems as a form of traditional ‘grey’ infrastructure. In 2007, Green Roofs for Healthy Cities established a charitable organization called the Green Infrastructure Foundation and raised funds to develop a half day training course on living green infrastructure and provide training in over 30 cities across North America (www.greeninfrastructurefoundation.org – See Programs). This experience led to the

COST-BENEFIT ANALYSIS OF GREEN ROOF VS. BLACK ROOF – PUBLIC AND PRIVATE BENEFITS

NATIONAL LEVEL RESULTS	GREEN ROOF SIZE (SQ. FT.)		
	5,000	10,000	50,000
IMPACT ON OWNERS / OCCUPANTS / INVESTORS			
Initial Premium, $/sq. ft. of roof (extra cost of installing an extensive green roof instead of a black roof)	(-$12.6)	(-$11.4)	(-$9.7)
NPV of Installation, Replacement, & Maintenance, $/sq. ft. of roof	(-$18.2)	(-$17.7)	(-$17.0)
NPV of Stormwater, $/sq. ft. of roof (savings from reduced infrastructure improvements and/or stormwater fees)	$14.1	$13.6	$13.2
NPV of Energy, $/sq. ft. of roof (energy savings from cooling and heating)	$6.6	$6.8	$8.2
Net Present Value* (installation, replacement & maintenance + stormwater + energy NPV)	$2.5	$2.7	$4.5
Internal Rate of Return (IRR)	5.0%	5.2%	5.9%
Payback, *years*	6.4	6.2	5.6
Return on Investment (ROI)	220%	224%	247%
OTHER FINANCIAL IMPACTS (LESS REALIZABLE)			
NPV of CO_2, $/sq. ft. of roof (emissions, sequestration & absorption)	$2.1	$2.1	$2.1
NPV of Real Estate Effect, $/sq. ft. of roof (value, rent, absorption & vacancy)	$120.1	$111.3	$99.1
NPV of Community Benefits, $/sq. ft. of roof (biodiversity, air quality, heat island, etc.)	$30.4	$30.4	$30.4

Source: (US GSA, 2011, "The Benefits and Challenges of Green Roofs on Public Buildings") www.gsa.gov

250 Hudson, New York, NY 2010 Award of Excellence Source: FXFowle Architects.

understanding that in order to develop green roofs and walls they must be seen as part of a larger range of living green infrastructure systems which include urban forests, bioswales, rain gardens, meadowlands, passive and active turf and wetlands. It also reinforced the fact that in order to move supportive policy into place, one must focus on senior levels of government. So in 2010, I founded the Green Infrastructure Ontario Coalition, a group comprised of six organizations that shared the perspective that we needed better policies from the Province of Ontario, to support the further development and protection of living green infrastructure. We spent over a year developing a comprehensive report on policy changes we were seeking from the Province of Ontario. (www.greeninfrastructureontario.org) In Canada, the provincial governments have legislative authority over city governments, and they also have significantly more funding for grey infrastructure projects. Hence it was logical for us to expand our activities beyond the City of Toronto in an effort to develop the broader market for living green infrastructure in Ontario, with the aim of replicating this model in other provinces and states. In 2012, we organized a conference entitled *Grey to Green: On The Economics of Green Infrastructure* in Toronto with over 450 delegates from across North America in attendance. During this conference we launched the *Green Infrastructure Declaration* (see below) in order to increase awareness of the living green infrastructure and the need for both public and private investment. More than 250 individuals have signed the declaration, which is meant to be a tool for use by advocates in other jurisdictions to promote supportive green infrastructure policy and investment.

Green infrastructure declaration

Past planning, design and development practices have turned our urban and suburban areas into vast areas of paved surfaces and dark rooftops that despoil our water and air and alienate our citizens from the natural environment and each other. Our communities have lost much of their ability to cool themselves through natural shading and evaporation, resulting in unnecessary energy and water use, air pollution and negative impacts on our health and well-being.

The time has come to reverse this trend by embracing Living Green Infrastructure technologies through policies and public infrastructure investments that protect, renew and restore ecosystem functions to our communities and generate local employment.

Given that Green Infrastructure provides multiple social, environmental and economic benefits to society, there is a basis for more widespread public policy implementation. Green Infrastructure technologies include:

- *Urban forests (street and backyard trees, existing remnant forests);*
- *Green roofs (intensive, extensive, and semi-intensive);*
- *Green walls (facades, living walls and biowalls);*
- *Green spaces such as turf, parkland, community gardens and boulevards;*
- *Rain gardens and bioswales;*
- *Greenways and green streets;*
- *Natural and engineered wetlands;*
- *Porous paving systems;*
- *Water harvesting, processing and distribution technologies used for irrigation; and*
- *Healthy soils and composting systems.*

Whereas Living Green Infrastructure:

... is a powerful and under-utilized opportunity for addressing climate change and reducing energy consumption by cooling hard surface temperatures

Kauffman Center for the Performing Arts, Kansas City, MO 2013 Award of Excellence Source: Jeffrey L. Bruce & Co.

through evaporation, transpiration, shading and by providing wind breaks;

... makes our communities become more resilient in the face of extreme weather events by reducing unnaturally hot temperatures in urban areas – the urban heat island effect;

... allows us to manage stormwater more effectively thereby reducing the risk and number of combined sewer overflows from overburdened sewage systems;

... improves water quality and facilitates the recharging of ground water resources;

... improves air quality by capturing airborne pollutants and filtering out harmful gases;

... is more labour intensive than conventional forms of grey infrastructure, thereby creating more local and regional jobs in manufacturing, design, installation and maintenance;

... complements grey infrastructure by extending the life expectancy of concrete, asphalt, and waterproofing systems;

... improves local property values and increases local tax revenues;

... enhances urban livability by providing opportunities for walking, bicycling, outdoor recreation and active lifestyles that reduce obesity and improve public health;

... facilitates community planning, community cohesion and involvement;

... supports numerous opportunities for local urban and suburban food production and social justice;

... encourages environmental education and community empowerment;

... supports renewable energy through beneficial use of biomass and improves rooftop solar PV performance;

... provides a place for native plant species, bees and birds; and

... supports improved mental and physical health within our communities.

Be it resolved that:

... the many proven benefits of Living Green Infrastructure warrant a strong, focused and immediate policy and funding commitment;

... we fundamentally rethink the ways we invest in infrastructure and reimagine how we could

design and rebuild our metropolitan and urban neighborhood areas;

... business, union, government and community leaders endorse Living Green Infrastructure as a national, provincial/state and local/regional government priority; and

... governments:

- *Recognize Living Green Infrastructure as an important type of infrastructure in all relevant policies and programs, and redirect funding for implementation of green infrastructure projects in our communities;*

- *Establish performance targets for Living Green Infrastructure such as a doubling of the urban tree canopy, and a 25 per cent reduction in the overheating of our communities;*

- *Fund Green Infrastructure planning, training and technical assistance for local communities;*

- *Support research into best practices and performance metrics and apply these measures to ensure accountability and track progress in our communities;*

- *Update building codes to encompass Living Green Infrastructure, and add compliance measures for water and air regulations that include living green infrastructure solutions;*

- *Lead by example in terms of adapting publicly owned buildings and land use practices to incorporate Living Green Infrastructure; and*

- *Encourage regulatory agencies to allow energy, transportation and water utilities to provide funding for Living Green Infrastructure for their own facilities and lands and to their broader customer community as a demand side management tool.*

Signature:

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Source: Green Infrastructure Foundation -Resources (www.greeninfrastructurefoundation.org)

5. SUPPORTING DESIGN PROFESSIONALS

One of the main challenges in developing a new industry is to agree on a standardized body of knowledge (best practices) then transfer it into the marketplace. The development of the Green Roof Professional (GRP) training and accreditation took more than seven years to complete but was instrumental in developing the industry. Multi-disciplinary groups of professionals worked together to develop training courses and resources for the industry, which then allowed us to establish an occupational standard and an accreditation exam. This key program has addressed the need for best practices and for unbiased, scientifically based professional training. It serves multiple functions:

- It provides a forum to bring experts together to determine best practices.

- It facilitates interdisciplinary communication between roofing professionals and landscaping professionals.

- It provides for specialization in traditional design professions such as architecture and landscape architecture and recognizes individuals for their knowledge.

- It provides a measure of protection against poor design, installation and maintenance practices, which are inevitable with a new practice but which, if left unchecked can harm the industry.

• It allows for continuing education of Green Roof Professionals (GRPs), in an industry which is evolving rapidly in terms of products, performance and practices.

• It provides a source of revenue for the industry association in order to continue to develop and deliver high quality professional training.

We offer three days of training focused on design, implementation and maintenance best practices, and a two hour multiple choice exam in support of the Green Roof Professional (GRP) accreditation. The first exam was launched in 2009, and now there are more than 600 accredited GRPs in the market. These core training courses will be provided through online, internet based training in 2014. We have developed a number of targeted training half day programs to support their continued education. These include *Advanced Green Roof Maintenance, Ecological Green Roof Design, Rooftop Food Production, Green Walls 101, Living Architecture and Sustainable Energy*, and a series of courses on Integrated Water Management for Buildings and Sites, with a goal of reaching net zero water. All of our training is peer reviewed and leading edge and is accompanied by resource manuals in English that are available for purchase at: www.greeninfrastructurestore.com.

Each year we celebrate excellence in design with our Awards of Excellence program that recognizes the designers of projects in different green roof and wall categories (intensive and extensive) for different buildings (multi-unit residential, small residential, commercial/ industrial). The Awards promote both green roof and wall projects that are designed to deliver multiple benefits through integrated design processes involving close cooperation amongst the building owner and all parties. We also recognize policy leadership, corporate member leadership and research leadership during our awards program every year. (For descriptions of many winning projects see: www.greenroofs.org - awards of excellence).

Biodiversity at Hood Canal, Quilcene, WA 2011 Award of Excellence Winner Source: Hadj Design.

Supporting Manufacturers

Developing a reliable supply of products for the market is a key leg in the stool of industry development for without them it would be impossible to implement thousands of projects across North America. Initially roofing membrane manufacturers were the most important players in supporting the development of the industry and as the sector has developed in North America, there are more dedicated green roof companies, those who derive 100 per cent of their revenues from the industry.

We work closely with our manufacturers to develop standards, most recently those associated with fire and wind uplift. Our manufacturers support our lobbying efforts at the local and regional government levels, and participate in the trade show at *CitiesAlive* and our local market development symposia. There are five manufacturer representatives on our multi-disciplinary board of directors which provide ongoing input and feedback on our policies and programs. Manufacturers also help to shape our training programs, providing substantive information and peer reviewing materials. Manufacturers who develop new products and services for the industry are profiled on our *Living Architecture Monitor* magazine website (www.livingarchitecture

Food production at The Ledge Kitchen & Drinks, Dorchester, MA 2012 Award of Excellence Source: Recover Green Roofs, LLC.

monitor.com). Manufacturers also play an important role in supporting research and development activities, product and process innovation, and ongoing education of the design community.

The development of a new industry requires effective communication and incentives for action amongst many different groups of people, particularly with living architecture systems such as green roofs and walls. Living architecture involves the integration of living and non-living systems, and therefore necessitates a high degree of multi-disciplinary cooperation in order to reach its full potential. For our 10th anniversary, we celebrated the work of more than 50 pioneers, from academia to government to business, who made substantial contributions to the development of the green roof industry in North America through a table top book called The Rise of Living Architecture. This provides insight into North America trends and insights into the lives and work of the people that make up the four legs of the industry in North America (www.greeninfrastructurestore.com).

6. CONCLUSION

The intense greening of cities requires the participation of many different professionals within society. It also requires civic engagement, with citizens that are informed and care about the place they call home. Having a green foundation, like the valleys and ravines in Toronto, is a major asset that we have been able to build upon in order to implement living architecture on our buildings.

The development of the green roof industry across North America has resulted largely from our ability to engage and fuel the passionate conviction of many leaders from different fields (policy, design, science, manufacturing), all of whom share in the belief that we must develop greener, healthier, high performance, restorative buildings - and that green roofs and walls have a critically important role in achieving this. The ability of green roofs and walls to deliver multiple public and private benefits that are in demand in cash strapped cities gives them a very special place in the toolbox of high performance, restorative building options.

In an increasingly crowded world, we must use all of the available space in cities through the use of green roofs and walls, as well as water storage, solar energy, fuel, food and wind energy. These are opportunities so vast, that we have barely begun to realize their full potential. Our existing roofs and walls are the great canvasses of this century, awaiting those poised to embrace living architecture and make a lasting contribution to a much better world. By 2022, we plan to bring another billion square feet of green roofing into being in North America and thousands of green wall projects, and we will continue to share our evolving understanding of how living architecture will help us all achieve greener, healthier and sustainable cities.

CHAPTER 2

EVALUATION, INNOVATION AND PERFORMANCE OF GREEN URBAN MARKETS

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ABSTRACT

After the Second World War, great economic development and urbanization processes have created megalopolises where green nature is absent. In the last few decades, green urban movements have become very prominent and dynamic. Special attention is given to technical and environmental issues concerning greening urban environments. However, market analysis and socioeconomic impact have not been at the forefront of discussion. This work describes the importance of marketing methodologies to understand market evolution and the role of the main actors in the value green market.

A "*glocal*" method of analysis includes a global overview of the green system, with local actions, focused on specific problems. In the global view of the green system, there are vertical analyses, with the description of their structure, conduct and performance. The horizontal view is related to information systems and identification of the main drivers of urban markets.

The analysis of factors affecting the quality of life and sustainability of urban areas includes very heterogeneous activities such as business and economics, human and natural resources, recreation, research, urban planning and socioeconomic change. All of these factors provide us with an introduction to green infrastructure performance in terms of landscape, rain water management, food supply, energy saving and others.

The local focus studies are specifically oriented, such as contingent evaluation, hedonic price system, multicriteria analysis, technical approach, total economic evaluation forecast evaluation or the interface between actors in green urban markets with the scale of sustainability.

There is a short description of some of the more significant methods of analysis and the possibility of combining them, looking for their synergies and accomplishing the goals for society welfare, with some conclusion and proposals.

KEY WORDS

Urban green areas, methodology, *glocal* marketing, evaluation, analysis.

1. INTRODUCTION

Green areas in city environments have been a long tradition in human history. There are clear examples in many cultures where gardens and green areas of wealthy families' properties were embedded in the urban landscape (Babylonia, Rome, Paris). However, urban agriculture for food supply was also a common practice for low income people. (Briz, J., 2004)

The rapid growth of megalopolises, forecasted at 70 percent of the population living in urban areas in the coming decades, may cause a "demographic bomb" where millions of people will be in urban quarters without basic services and without any contact with nature. Therefore, it is urgently needed to change the landscape from grey to green, and improve living conditions, save energy and reduce waste and the carbon footprint.

While technology for urban planning and building development has been improving in the last few decades, the integration of nature in our environment is far behind. Urban green areas can be found on buildings (roofs, walls, indoors, balconies), ground (trees in the streets, parks and gardens, railways) or moving buses, trains and trucks.

It is commonly accepted that urban green areas improve the quality of life, but their implementation can be costly. In order to compare the results in different cities, we need to have a commonly accepted methodology to evaluate the costs and benefits, the population and the impact on the environment. We describe in the following figures some of the factors affecting the quality of life and green area performance as main indicators for innovation and research in the field of green urban markets.

Community garden in terrace. Paris. Source: I. de Felipe.

2. SCENARIOS FOR INNOVATION IN GREEN URBAN AREAS

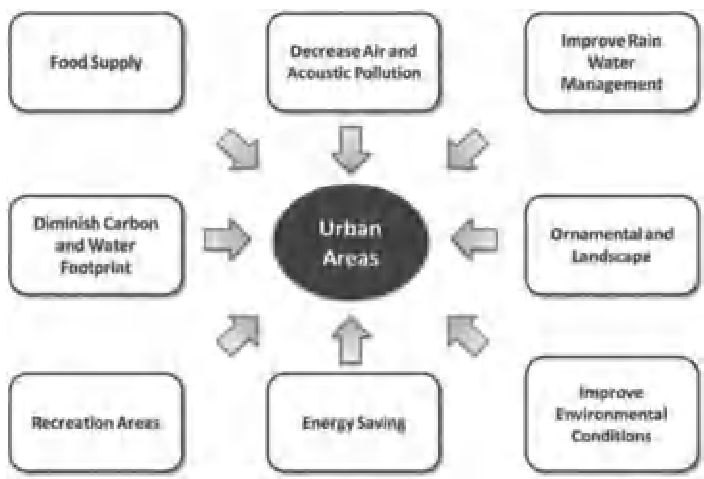
Green urban areas have been improved in the last few years, where innovation and technology have improved. These include, but are not limited to:

- Botany, substratum and artist design: Innovation in these areas is fundamental for urban greening development. The combination of botanic and substratum science with artist design allows for masterpieces in the field. For example, Dr. Patrick Blank, designs green walls all over the world in different climates and urban conditions (Blanc P., 2011). Green roofs are becoming one of the most dynamic areas, considering they have been the "forgotten fifth façade of our buildings. They are ugly and the last urban frontier" (Peck, S., 2008) Green roof projects are classified as intensive or extensive and applied on residential, institutional and industrial-commercial buildings.

- Water management: Hard covered surfaces on buildings and streets increase the volume of water runoff, causing flood problems. Green roofs combat this problem by storing rain water. In countries such as Germany there are fiscal advantages for the green roof owners based on this aspect. There are several studies about green roofs for the retention and delay of runoff to prevent urban flooding (Lee, E; Jang, H; Ahn, G. 2012). Water retention depends on substrate depth and composition. In the German FLL guidelines, the annual average rain water retention is 55% in an extensive roof of 100-150 mm depth. Therefore, stormwater management is another important effect, as it can reduce the flow to the public system by 56% (Wenjie, Li; Myers, D.N. 2012). It also reduces the amount of nitrogen and other pollutants going to the watershed. There is also an improvement of wildlife habitat. Birds, butterflies and others are regular visitors of green roofs.

FIGURE 1. FACTORS AFFECTING QUALITY OF LIFE AND SUSTAINABILITY OF URBAN AREAS

FIGURE 2. GREEN AREAS PERFORMANCE



- Pollution control: Plants capture CO_2 and dust in their leaves and roots and substratum fixes lead and cadmium, acting as air filters with an improvement in environment quality. Gases originated in the burning process, such as central heating in buildings, contain CO_2 (5-30 per cent) and NO_x which contaminate the air. When NO_x mixes with atmospheric water, they create nitric acid (HNO_3), which is very dangerous for the environment. However, there is a possibility of reducing it with crystalline urea (32.5%) at a given temperature, transforming NO_x to N_2. For this task, the company REPSOL in Spain is using a registered product, AdBlue (www.gasoleosgetafe.com/ adblue.asb). Another way to eliminate HNO_3 is by using microalgae crops, which is used as fertilizer. Urban particulate pollution is harmful to human health. Traffic and central heating in buildings are some of the origins and measures should be taken to control and diminish their level. In relation to urban air pollution, vegetation is a passive filter, capturing particulates. Intensive greening has to consider the traditional trees and ornamental plants in parks and streets, plus green buildings (roofs, walls, insides). Studies have show the benefits of green roofs as passive filters of airborne particulates (Speak, AF; Rothwell, J; Lindley, S; Smith, C. 2012).

- Building materials: New products appear in the market with properties that improve the conditions of the green buildings, water proof and root-proof construction and so on. The period for roof replacement is also extended when there are green areas, as plants diminish the impact of solar radiations.

- Climate regulation: Plants have a positive impact on the urban climate (indoor and outdoor). Green roofs reduce the urban heat island effect, which is significant in great metropolises. Energy savings for buildings is another positive of green areas. Surfaces absorb solar radiation with urban heat island effects. However, plants reduce the thermal energy through evapotranspiration and reflection of solar energy cooling systems and maintain the building at lower temperature.

- Biodiversity: A green urban environment is proportionally richer in biodiversity than rural areas. Flora and fauna offer more variety in the green urban areas and have the potential to maintain biodiversity.

- Carbon, energy and water footprints: We can diminish their impact due to the advantage of self-consumption of food products in urban agriculture, with a more simplified logistic distribution.

Green wall. Paris. Source: I. de Felipe.

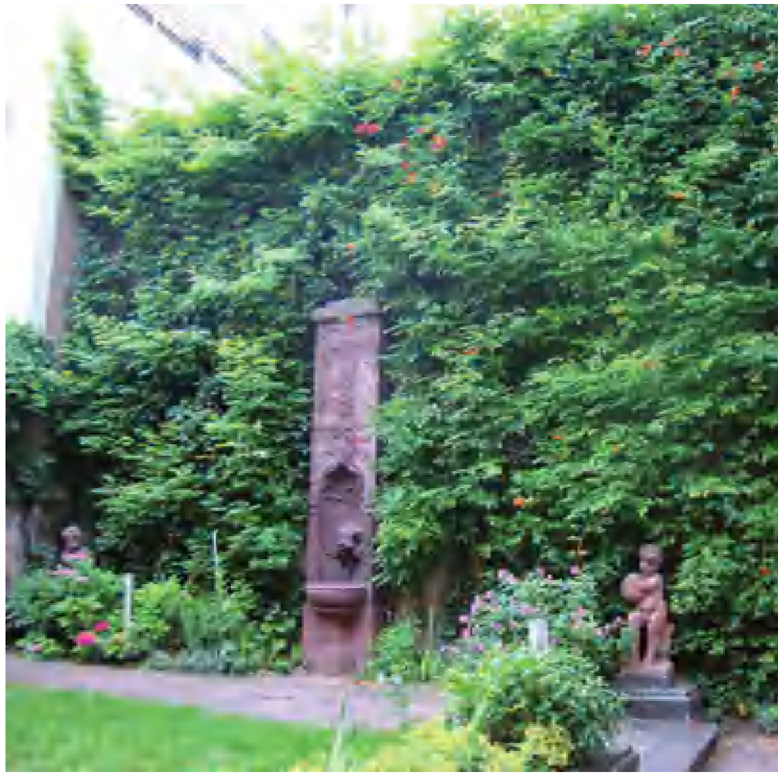
- Energy and noise isolation: Surfaces (walls, roofs) covered by plants are isolated from energy radiation and noise contamination, as it has been tested in several research studies. Simultaneously, there is an absorption effect by the plants when they capture gas and heat emission from central heating in buildings and buses. Another interesting area of analysis is the performance evaluation of green roof and shading for thermal protection of buildings (Kumar, R; Kaushik, S. 2005). Green roofs maintain a cooling potential, with an average temperature more adequate for building maintenance. Photovoltaic panels have increased performance when they are over a green surface. Green roofs also reduce noise pollution. According to some research done at the Centre for Advancement of Green Roof Technology, the sound transmission loss increased 5-13 decibels in low and mid frequencies and in the case of high frequencies 2-8 decibels (Connelly, M; Hodgson, M. 2008). Therefore green roofs are recommended in urban areas near airports.

- Quality standard regulations: Similarly to how smart cities and efficient buildings can be certified according the LEED standard (Leadership Energy Environmental Design), there is a need for a Green Building Standard which classifies and certifies the quality of the green constructions.

- Urban planning: International, national and local institutions have the responsibility to steer new urban planners toward adequate regulations for improving the urban environment. Some cities (Berlin, Toronto, Chicago, Copenhagen, Mexico and Nantes) are leaders in local regulations which may be examples for other urban centers.

- Landscape: Architects, agronomists and designers may change the urban landscape from grey to green, by creatively choosing and combining native and foreign plants (Blanc, P. 2011).

- Moving green areas: In a new area of innovation, buses, trucks, and trains covered by green roofs may circulate throughout the urban streets (http://chil.org/produccion-vegetal/group/pronatur/page/proyectos-emblematicos-de-naturacion-urbana).



Green wall. Goethe House. Frankfurt. Source: I. de Felipe.

- Hedonic values: Green areas offer places for entertainment, spare time, sports or meeting places for people. These dimensions are not considered in regular market transactions. Green roofs provide recreation space (Jim C.Y. et al. 2006) where dwellers and visitors may spend time with friends and enjoy a social life with neighbors. They could strengthen the community cohesion by improving formal and informal relationships, with discussions about urban agriculture and getting new opportunities to understand climate change and the role of vegetation. As a public recognition of the social benefit of green urban areas, there is a yearly nomination of a European Green City: Stockholm 2010, Hamburg 2011, Vitoria 2012, Nantes 2013 and Copenhagen 2014.

3. GREEN URBAN MARKET EVALUATION: A GLOCAL METHODOLOGY

Citizens need a friendly environment, shaping the nature in their surroundings. However the financial resources available are limited and their allocation is a matter of political decision. Market research can help in the decision process with the analysis of alternative possibilities and evaluation methodologies with the information and data required.

As the first step, we have to find the equilibrium between the social demand of green areas and their potential supply. The methodology has to be implemented with information and data for empirical analysis ending with practical results and the appraisal of sustainable solutions.

Analytical methods may be quantitative and qualitative. Thus, market evaluation is a useful tool to understand the elements which influence the quality of life for citizens, in a friendly and sustainable environment where green areas play an important role. The utility may be extended to public and private institutions, firms and social organizations, to evaluate green urban performance.

Green panel exhibition. China. Source: I. de Felipe.

Some of the goals of city dwellers are a healthy environment, nice landscape, and optimization of natural resources. Smart cities with green areas are typical proposals in urban planning. Green areas include urban agriculture with food and nonfood services (landscape, entertainment, environment). Modern urban areas should provide a great variety of services not only for the residents, but also for workers living outside the city but traveling there every day. There is a complex framework that many factors impact: local regulation, habits of dwellers, urban planning, natural resource availability, food, water and energy disposals and residues.

In order to reach these goals, it is necessary to follow a methodology, combining resources available with capacity to organize and use them.

We propose a "*glocal*" approach, which means a global view of all the existing problems in the urban area, their interrelationships, origins and evolution. The next step is the local analysis of some of the more relevant issues, with proposals of different solutions.

In this framework, there are three scenarios to study: good and services, information and economic-financial flows. Each of them has specific dimensions within the areas of structure, conduct and performance.

This methodology has traditionally been used in several economic sectors, such as industrial organization, and they may be helpful in our case of green urban areas development.

The advantage of this methodology is to consider not only the urban equipment, such as ownership of buildings, streets and parks, but also city planning, bureaucracy barriers, potential corruption (behavior) and final results (performance).

The issue is to pay attention to all the actors participating in green urban areas, coordinate their preferences and classify the potential solutions under a sustainable horizon.

The *glocal* methodology is a mixture of the sector analysis, combining qualitative and quantitative techniques, looking for synergies according specific and general goals (Johnson R.B et al. 2007, Weiss L 1971).

There is a preliminary period deemed exploratory or "global", followed by the specified or "local" one, which provides the information for the evaluation.

The qualitative analysis may be performed through a focus group's study of how activities and conduct of the socioeconomic agents are developed (Bogdan R, Taylor S.J 1978). The interaction among the members of the focus groups allows for capture of their opinion, their affinity or differences between them, their habits and other details, difficult to get through a regular inquiry.

In some way, to understand the reaction of people to market situations is complimentary to the quantitative analysis, with an orientation toward the structure and performance of the society. It is important to compare experiences in other regions and countries, problems and solutions applied, within the framework of the paradigm.

We define a paradigm, recognized by a significant group of experts, as the best way to analyze, understand and resolve the more important problems on a given date. However, the dynamics of the market may cause the paradigm to become old fashioned and may need to be updated with new information.

In Figure 3, we describe the main steps of the analysis:

1st Step. Introduction:

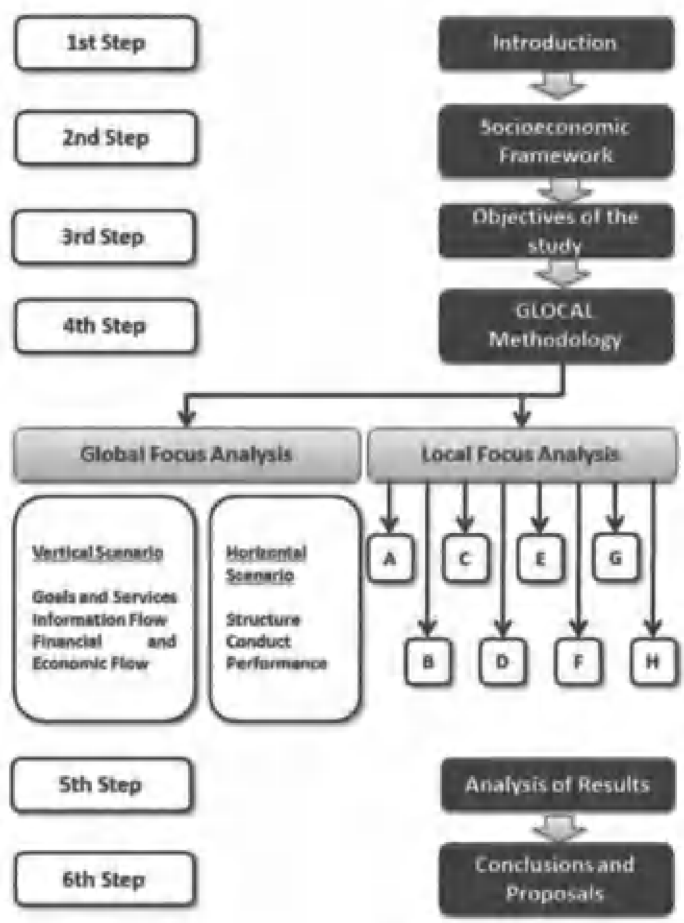
A short description about the origins and motives of the research in green areas.

2nd Step. Socio-economic framework:

In this section we include the major economic and social dimensions of a Green Urban Market (GUM) under analysis. It may be an approach of its historical evolution or a transversal analysis of various scenarios in a given period.

The analysis of the framework will allow us to meet the most significant problems that affect the sector, its social impact and its historical pathway.

FIGURE 3. METHODOLOGICAL STUDY OF THE GREEN URBAN MARKET



3rd Step. Objectives of the study:

This phase is crucial for the achievement of a useful and efficient study. First it has to establish the priorities and whether the objectives are general or specific.

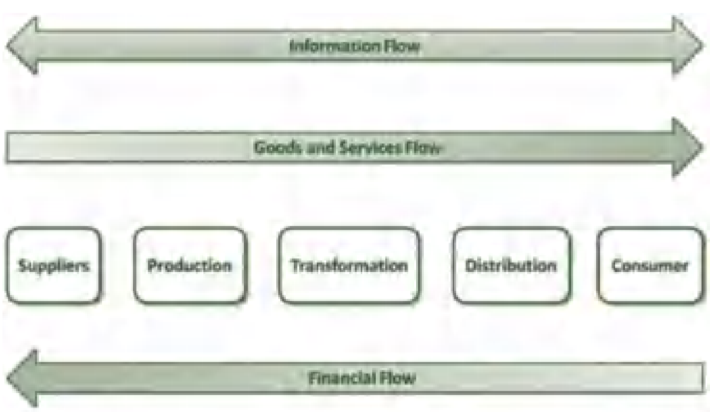
The method can be described qualitative and/or quantitative looking for the easier way to conduct the study. They may have a commercial or economic dimension (income, sales, market share and risks), social dimension (creation of jobs, development of an area) or promote innovation and competitiveness.

4th Step. Glocal methodology:

This methodology seeks to combine a global vision of the Green Urban Market (GUM) with specific local performance. Although it offers the possibility of analyzing them separately according to the objectives and constraints of time and budget, the ideal situation is if both are merged in the *glocal* situation (Briz, De Felipe 2013).

Global vision includes three vertical scenarios that correspond to the different flows that run through the Green Urban Market, from the supplier to the user-consumer and vice versa. First, we can mention the movement of goods and services which the supplier passes to the designer, architect, builder and finally to the user-consumer. Second, is the financial flow that moves in the opposite direction from the user-consumer to the supplier, paying for goods and services received.

FIGURE 4. VALUE CHAIN SCHEME



The third is the flow of information that moves in both directions and influences the functioning of the two previously mentioned streams.

The horizontal stage includes three groups of factors in the organization and development of the Green Urban Markets: *structure, conduct and performance*.

The structure refers to organizational systems of the Green Urban Market, and it has a number of dimensions that allow evaluating and comparing of different situations.

- Organization business, such as level concentration of the companies in the sector, may use some index such as the C. Thus, the C4 is the quota market of the first four companies, the C6 the first six and so on. It is an easy-to-identify system and is sometimes used by the public sector to establish concentration limits which may violate competition and the proper functioning of a market. Another indicator is the Gini concentration index that relates the percentages of firms to the percentages of sales. Their range of variation is zero (minimum) to one (maximum). The analysis of their historical evolution is useful for structural changes in a sector.

- Barriers to entry and exit.

- Organization of commercial channels. A structural dimension of the Green Urban Market concerning relations between actors of the chain and its organizational form. Three scenarios can be considered: horizontal, vertical and diagonal relationships.

- Differentiation of the product throughout the Green Urban Market. We may analyze the

Green façade in Hoy An. Vietnam. Source: I. de Felipe.

range of products (plants, garden design, prototypes and so on).

The *conduct* includes the behavior of the social and economic agents that operate in the Green Urban Market and, in many cases, are related to ethical and moral issues. It involves the analysis of the conduct of the actors involved in the Green Urban Market, both public and private, with the problems within the interface between the agents where we should evaluate their conflicts and its frequency (Theuvsen, 2007).

Another dimension of interest is the failure or absence of regulations in urban green markets. Evaluation can be done taking into account the complaints of citizens and their social impacts.

Inter-company relations offer a number of modalities that can be grouped by:

- Features hidden, when the leading actor cannot check all the characters of the product, which offers certain negotiating advantages

- Hidden intentions. When the actors can influence after the contract is signed.

- Other aspects of conduct: industrial espionage, unfair competition and fraudulent practices in the marketplace.

Finally we have the *performance*, reflecting the result of the elements of the Green Urban Market.

The challenge is to identify a set of criteria that allow the evaluation and comparison of various situations. Some of them are set out below.

a) Effectiveness and efficiency in management.

The first relates to the level of achievement of the objectives proposed by each agent. The greater the divergence between them, the less the effectiveness is.

Efficiency: It may be technical efficiency (degree of performance of a productive factor such as energy, water, human resources) or economic (benefit/cost ratio)

b) Transparency

It involves the existence and availability of information for all those involved in the

Green wall. Singapore. Source: I. de Felipe.

management of the Green Urban Market. Some actors have a privileged position in getting information in future urban planning and therefore get special benefits.

c) Trust

This is related to transparency and information. The criteria to evaluate the confidence depend on the contracting party, seller or buyer. In transactions, there is asymmetry in information, where one of the parties knows more than the other and takes advantage of it for their benefit. Akerlof, Nobel Prize winner for Economics in 2001, studied how to transmit information to gain the confidence of the other. It is also worth considering, according to Stiglitz (also a Nobel Prize winner) how to discover the counterpart information if there is no confidence (Hartford, 2006).

Many actors in the green markets do not have trust in the existing rules, where policy and economy are strongly connected, and speculative movements give illegal benefits to the involved persons.

d) Dynamism

The dynamics of the Green Urban Market may be related to the capacity to solve the problems raised. This is determined by a number of factors:

- The flexibility to meet the final wishes of the user-consumer, transmitting rapid and objective information, improving transparency and mutual trust.

- Overcoming the structural problems concerning the interaction of small and medium-sized enterprises (SMEs) with large companies, mutual cooperation and modalities (cooperate and compete) co-competition between firms in the same industrial district. In building construction firms, there are big concentrations of power with influence in the policy makers who simultaneously have market advantages through their bargaining power face to SME and individuals.

e) Innovation

It shows the availability of a company to incorporate innovations. Innovations offer a wide range of possibilities (technical, organizational and management and training of human resources, among others). We have previously mentioned some dimensions of innovations.

f) Adaptability

The business world is subject to a changing environment. A system of measure to be

FIGURE 5. BASIC MATRIX OF THE GREEN URBAN MARKET

BASIC MATRIX OF THE GREEN URBAN MARKET			
	STRUCTURE	CONDUCT	PERFORMANCE
Flow of goods and services. Logistics	M11	M12	M13
Flow of information	M21	M22	M23
Financial economic flow	M31	M32	M33

applied is the rate of business survival, accounting for the companies that survive and their characteristics (size, activity, organization).

Adaptability also can be measured by identifying the leading companies of the sector and the successful strategies employed. To do this there are commonly-used techniques of comparison such as benchmarking (Bremmers, 2004).

g) Level of conflicts

This dimension refers to disputes (strikes, demonstrations, lockout, among others) which may be quantified by number of days, hours, or jobs lost. The causes can be varied and require a detailed analysis.

We have a table shown in Figure 5 to show crossing horizontal and vertical stages.

Below are each of the corresponding matrix cells M_{ij} according to rank (i) or (j) column, indicating some of the identifying factors:

- Flow goods and services (logistics) - structure (M11)

- Business concentration
- Barriers to entry and exit
- Commercial channels
- Product differentiation

- Flow goods and services - conduct (M12)

- Conduct chain actors
- Balance power negotiation
- Coercive practices
- Action of public institutions

- Flow goods and services performance (M13)

- Ratio benefit-cost
- Sustainability
- Conflicts between actors
- Green building know-how availability
- Innovation evolution and sources

Garden on terraze. Paris. Source: I. de Felipe.

- Flow Information - structure (M21)

  • Public information channels
  • Private information channels
  • Organization of traceability
  • Professional associations
  • Information in the short, medium and long term

- Flow information - conduct (M22)

  • Existence of privileged information
  • Free access to information
  • Abuse of sources of information available
  • Distorted information

- Flow Information - performance (M23)

  • Vertical transparency in the Green Urban Market
  • Horizontal transparency inside every link of the Green Urban Market
  • Level of trust between agents of the Green Urban Market
  • Existing risks and their co-responsibility

- Financial economic flow - structure (M31)

  • Organization of the financial system
  • Financing channels control
  • Monetary and fiscal policies
  • Degree of concentration of public and private financial companies
  • Degree of internationalization

- Financial economic flow - conduct (M32)

  • Discrimination in the financial and credits assignation
  • Financial bureaucracy in green urban programs
  • Instability in the financial and economic markets
  • The existence of abusive practices in the interrelations of the actors of the Green Urban Market should be covered by legislation facilitating mechanisms to prevent them. For fear of reprisals, weaker agents retract denounce cases of abuse suffered. Hence, the importance of the existence of bodies of the

Green wall. Santander. Spain. Source: I. de Felipe.

administration who can deal with complaints that maintain their anonymity.

- Financial economic flow - performance (M33)

  • Comparative analysis with other countries (GUM)
  • Financial cost in the Green Urban Market evolution
  • Facilities for cooperatives and neighbor associations
  • Participation of SME in local programs
  • Actions of the international organizations (WGIN, IGRA)

The *Specific Local Approach* (SLA) tries to answer a question of specific concern in the whole Green Urban Market. There are different possibilities:

A. Dynamic analysis of the Green Urban Market (GUM): Where do we come from? Where are we? Where are we going? Study of trends, seasonality, cycles or evolution of types of enterprises and their associations. According to the Delphi method, using sequential interviews with experts can help with GUM forecasts.

B. National or international comparative analysis with a selection of good institutional and business practices

C. Analysis of competitiveness in different sectors of GUM taking into account the contributions of M. Porter, in the so-called Competitiveness Diamond (Porter M.E. 2008)

D. Study of the interaction among actors in the GUM. Contractual relations, model contracts and trust levels are aspects to be considered.

5th Step. Analysis of results:

In this phase we proceed to evaluate the results of the applied methods (*glocal*).

Branly Museum. Paris. Source: I. de Felipe.

To do this, consider the identification of strengths and weaknesses, threats and opportunities (SWOT matrix) as well as other dimensions in line with the set objectives.

6th Step. Conclusions and proposals:

The study should highlight key findings and subsequent proposals for action that allow achieving the set objectives.

4. FINAL CONSIDERATIONS

The previously described *glocal* methodology combines structural and conduct dimensions within a dynamic scenario, were logistics, financial flows and information overlap in the green urban markets. It calls attention to the complexity of the transactions usually carried out in the GUM. At the same time, those elements contribute to identify problems and possible solutions.

The global matrix of the GUM is self-reliant with vertical and horizontal stresses. In the vertical sense the intensity and efficiency of the flow of goods and services interface with the information and financial flows. The strength of any one of them supports the better functioning of the others.

Similarly, it occurs in horizontal stresses, where the structure of each of the mentioned streams affects their conduct and, in turn, the performance.

Sometimes due to lack of time, knowledge, or budget, studies are very partial. Thus, results and corresponding actions are difficult to develop. Hence, the failures are widespread in an issue where the news media and social pressure are very high.

Green Urban Markets have traditionally been outside traditional analysis and performance analysis. Administration has had strong influence through urban planning, and economic and political forces interact for more favorable regulations. However, there is a new trend and citizens wish to have a direct role in the decision process, influencing their welfare and environmental conditions.

Here is where the market forces may have an active role, within the framework of the regulation. Therefore, the objective analysis of the market and the identification of the supply and demand, institutions and actors, through periodical studies and methods, is the first step to clarify and understand the situation, evolution, risks and opportunities.

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CHAPTER 3

GREEN ROOFS IN POLAND: LANDSCAPE AND SUSTAINABILITY

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ABSTRACT

The aim of this chapter is to present the key issues concerning the development of green roofs in Poland within the context of the quality of urban landscape and sustainable architecture. The authors share their views and experiences concerned with the main stimulants and handicaps to the growth of the green roof industry, introduce trends in technologies, address the educational background and discuss major policies aimed at supporting the delivery of green roofs to the professionals and stakeholders in the country.

KEY WORDS

Green roofs in Poland, policy and regulations for green roofs, delivery of green roofs, environmental education, factors stimulating and hampering green roof industry, green roof technologies.

1. INTRODUCTION AND GOALS

Modern green roof technologies became available in Poland in the late 1990s. It is estimated that c.a. 1.0 million square meters of green roofs are built annually in the country, however these estimates are based on the observations of the general trends in the construction market, and no evidence based data or monitoring is available yet (e.g. Kożuchowski 2008). Despite the figures' sizeable looks at first glance, the conversion provides a little more than 0.02 sqare meters of green roof area per capita, equal to about 10% of the size of the leading markets (Germany, China, USA, China), hence showing aptitude for further development in the sector.

Still, it is observed that the Polish green roof market is growing on a regular basis and the the interest of investors, architects, and construction and installation companies in this technology is becoming more intense. The most popular business directory in Poland (Panorama Firm) records nearly 250 companies offering green roof products and services overall and the equivalent of the phrase "green roof" records about 2.0 million results by Polish Google.

It is a common practice in major Polish cities that the big investments are covered with living roofs. However, a vast majority of green roofs in Poland are installed on the parking decks and far less are placed on the rooftops, which is specifically due to the structure of the real estate and construction market: most of the new developments consist of housing estates and business parks.

The term "green roof" is not directly mentioned in any of the Polish law. This kind of green infrastructure is referred to only indirectly in national legislation. Moreover, there are no measures that would help rate the value of a green roof as natural compensation. Along with growing land prices in the country, many investors, especially real estate developers, decide to install green roofs as a natural compensation instrument.

Green roofs have entered the canon of Polish architecture, as seen in many examples of office buildings and a number of other public and commercial investments. Precursors of green roofs in this context are undoubtedly the Supreme Court (2000) and the Library of the University of Warsaw (one of the largest and most beautiful public roof gardens in Europe with an area of more than 10.000 square meters built in 2002). Green roofs as a living "fifth façade" also appeared on such well-known sites such as the Copernicus Science Centre, the National Stadium, the Museum of the History of Polish Jews and the Golden Terraces shopping center in Warsaw, opera house in Bialystok and railway stations in Wrocław and Katowice. Examples of spectacular green roofs include exclusive high-rise apartment buildings such as Sky Tower in Wrocław and Daniel Libeskind Tower in Warsaw along with the vast majority of office buildings, for example, Platinum Plaza, Poleczki Business Park in Warsaw at the airport and Olivia Business Centre in Gdansk and many, many others. Green roofs can also be found in virtually every new housing estate (e.g. Kożuchowski 2013).

The purpose of this chapter is to describe general characteristics of the use of green roofs in Poland. Therefore, the authors indicate the directions of development of the technology in local conditions, discuss its factors and characterize the exemplary methods of education and delivery of the green roof concept in Poland. In the final part, the policies of Polish cities towards introduction of green roofs in line with sustainable development and environmental protection are introduced.

2. APPROACH

In the first stage of work, the research object presented in this chapter was identified. The data collected by the authors are derived from both theoretical materials and their own professional, scientific and practical experience on green roofs in Poland. Topics delivered in this chapter are presented in five major thematic groups:

- Green roof technologies – general trends in Poland
- Factors stimulating the development of green roofs in Poland
- Factors limiting the development of green roofs in Poland
- Education about green roofs in Poland
- Policies of Polish cities towards implementation of green roofs

The authors used methods of unobtrusive observation together with content and data analysis, which is recognized as one of the basic tools in scientific research. The first stage involved collection of general information on

New York City's Meatpacking District. Elevated public park. Photo Courtesy: Greenroofs.com; Source: ZinCo.

the Polish green roofs market and identification of the key problems in the use of green roofs in Poland over recent years; from the 1990s until the present day.

The assumptions gave rise to the second phase of work, which is a comprehensive characterization of the key issues in the evolution of green roofs in Poland. Trends in the installation of green roofs and a review of the literature and market data of the functioning of green roofs were addressed. Particular attention was paid to education in topics related to green roofs. Concomitantly issues relating to the limitation of rainwater losses and reduced CO_2 emissions were discussed within the context of introducing green roof policies in Polish cities. In determining the internal and external factors driving and limiting the development of green roofs in Poland, the authors applied indirectly to the SWOT analysis. The entire publication is a summary indicating the most important issues concerning the development of green roofs in Poland.

3. GREEN ROOF TECHNOLOGIES – GENERAL TRENDS IN POLAND

Specifics of the Polish real estate market determine the prevalence of intensive greening. Customers in the real estate market are increasingly driven by the proximity and quality of green space, so green roofs are taking advantage of a great significance in marketing policies. Well-developed property with roof gardens are often perceived as adding value to the investment.

Living roofs are commonly installed onparking decks with the aim to serve practical functions: communication, recreation and aesthetic purposes enriching the urban spaces with tall trees, shrubs, paths, benches, playgrounds, fountains and all other forms of landscaping. Greenery on the roofs of multi-storey buildings and industrial properties in form of extensive green roofs, which do not serve utilitarian purposes but allows for reconstitution of biologically active surfaces, are installed much less frequently. It is estimated that the ratio of intensive and extensive green roofs is 80% to 20%. Multi-layer structures remain dominant solutions along with marginal interest in single-layer and pitched roof greening which is also uncommon (e.g. Kożuchowski 2013).

The process of green roof installation is often a sensitive issue. Contractors repeatedly complain about difficulties in execution of the work due to the lack of an open front and/or design changes. This leads to situations where installation of a green roof is interrupted, delayed and finally executed in a hurry, so it is difficult to avoid technical problems and, consequently, defects. Appointment of an experienced construction supervisor for green areas keeping control of the proper green roof application still remains an uncommon practice.

The industry guidelines for green roofs are not available, so some of the professionals refer to the FLL guidelines, though still the knowledge of these standards is rather low.

Such a market situation means the majority of green roofs are performed using the inverted roof technology systems. The most common application involves the following types of construction materials:

• **Vegetation** – Shrubs and coniferous trees in line with lawn spaces are the predominant planting forms. Designers very often tend to apply monocultures, mostly guided by aesthetic considerations with disregard to the habitat requirements of plant species. Tall trees are imported, mainly from Germany. In the case of extensive roofs, mostly pre-vegetated *Sedum*-moss mats are designed. However, due to the high prices, use of mats has commonly switched to cheaper solutions in the stage of installation; to containers and plugs primarily, and occasionally in the form of cuttings or dry seed mixtures.

• **Thermal insulation** - Due to the substantial amount of inverted roofs, waterproof XPS and EPS insulations are most commonly used for installations.

• **Waterproofing** – Due to the costs and wide availability, bitumen membranes are most commonly used for waterproofing on green roofs. Materials like EPDM, PVC or TPO which require both experience and specialized equipment are applied much less frequently. Roof felts used for green roofs are mainly imported due to the fact that domestic products do not provide testing to confirm lack of root penetration.

• **Geotextiles** – Needle punched nonwoven geotextiles are dominant, which is due to the relatively low prices, wide availability on the Polish market (a few domestic producers and a wide range of imported materials) and the very limited technical awareness in the sector. Technical requirements of geotextiles are occasionally integrated into the projects.

• **Drainage course** - In solutions planned by the design studios, the shaped rigid plastic boards are prevailing, which is due to the conviction of water storage necessity on the green roof. Solutions with other types of drainage layers are used less frequently, although mineral or recycling aggregates are mostly used in low-budget projects with drainage matting practically unknown. Drainage mats offers are limited to imported materials, mainly from Germany.

• **Vegetation support course** - Specificity of the Polish market provides that green roof substrates are often used at high thickness (even up to 1 m); the mineral filling substrates are seldom indicated in the projects. Substrates are produced on a relatively small scale by a few manufacturers concentrated in the interior of the country, which affects their availability and price (transportation). Combined with the limited professional awareness in the sector it results in the common use of topsoil acquired on site. The

Extensive green roof, Copernicus Science Center in Warsaw, Source: T. Pijarczyk.

growing medium produced in Poland is characterized by a large amount of organic components. Due to the geological determinants, the palette of natural aggregates is limited, which leads to the use of primarily crushed brick and expanded clay as absorbent aggregates. Since 2007, the marketed substrates require consent of the Ministry of Agriculture and must comply with some basic quality restrictions.

4. FACTORS STIMULATING THE DEVELOPMENT OF GREEN ROOFS IN POLAND

Increasing land and real estate property prices in urban areas in line with the legal obligation of compensation for the destruction of natural open space along with local limitations in the load on the sewing system remain predominant factors stimulating development of the green roof industry in Poland.

The notion of a green roof is not expressly mentioned in Polish law. Issues related to green roof installation have been regulated since 2002 only by the ordinance of the Minister of Infrastructure. This provides that 50% of the green roof surface can be treated as a biologically active area characterized as terrain with a ground surface, including surface water, arranged in a way that ensures conditions for natural vegetation, as well as 50% of terraces and flat roof surfaces not smaller than 10 square meters with the same ground conditions (e.g. Piątek-Kożuchowska 2010).

In spite of constraints, the current legal status in Poland contributes to the application of green roofs in the construction industry. In Poland, in spite of the impact of the global recession, the increase in investment in the housing sector keeps continuing with some fluctuations. According to preliminary data, 129,588 dwellings were completed between January and November 2013, i.e. by 4.6% less than in 2012 (when there was an increase of

Port Townsend private home. In the Olympic National Forest in Washington State. Source: Greenroofs.com; Photo Courtesy: Xero Flor America.

18.7%) and 13.2% more than in 2011 (GUS 2013).

Increasing housing development is associated with green roof surfaces. The current Polish legislation imposes certain restrictions in relation to the possibility of building plots. This is especially true in big cities, where land prices as well as housing density are high and require maximum use of the plot area for development. That is why green roofs have become a common tool to recover part of the surface of construction sites for further development.

Polish law specifies that a green roof could provide 50% of the environmental compensation for a biologically active area occupied under the building. Due to the application of this green infrastructure, developers can built over larger areas of building plots. Examples of the investment of the entire country suggest that green roofs are becoming the technology for which demand is constantly growing and affecting the activity of industry companies. Due to this fact, the increasing competition among design companies and contractors contributes to a gradual lowering of the cost of implementing green roofs.

Increasing urbanization in Poland results in problems with the extensive waterways and shows the growing need for offsetting storm water management to improve the sewer systems, which are primarily combined systems. In recent years the seasonal floods have tended to cause severe damages across the country, especially in settlements and infrastructure built in urban areas and along rivers.

5. FACTORS LIMITING THE DEVELOPMENT OF GREEN ROOFS IN POLAND

In Poland, there is a group of a few basic barriers that limit the rate of input and the dissemination of green roofs.

The first thing to be mentioned is an insufficient level of education and public awareness of the functioning of green roofs (technical, environmental, economic aspects). Polls indicate (e.g. Radziszewska-Zielina 2009, Kadej 2010) that the society in Poland (especially in big cities) recognizes the positive ecological meaning of green roofs and their influence on environmental quality improvement. There is a need for universal and reliable knowledge about the functioning of this type of green infrastructure because green roofs are still often seen as a solution that is too expensive and extravagant. Among other things, this is due to the common stereotypical approach to housing in Polish society. These factors mean that the introduction of green roofs on private family houses or multifamily buildings (apartment blocks) belonging to cooperatives or condominiums is still not prevalent enough.

Another problem is the lack of adequate legislation implementing reduction of fees and subsidies that could motivate investors to make green roofs (especially on flat roofs). Under the relevant legislation the establishment of green roofs is not implemented by state or local governments as an environmental friendly investment (e.g. lack of common practice introducing regulations on green roofs in local development plans). These are, for example, the reduction of fees for drainage of rain water (water retention and storm water drainage relief) and tax cuts for buildings or financial incentives for investors, for example, due to the reduction of electricity consumption, etc., as has happened in Germany or Switzerland.

Inverted green roof on parking deck in Warsaw, photo P. Kozuchowski.

The Williams Engineering Building Northern Alberta, Canada. Source: Greenroofs.com; Photo Courtesy: Bioroof Systems.

One of the obstacles is the lack of separate standards and guidelines related to the design of green roofs adapted to Polish conditions (German DIN standards and FLL guidelines are still used, which are not always adequate for the Polish climate conditions, technical solutions, material and economic conditions and others). This is connected to the lack of continued research aimed at identifying solutions for the design, construction and maintenance of green roofs. In Poland, for example, objective methods for determining the degree of compensation of biologically active area provided by green roofs are still lacking. Currently, the Polish law that regulates this issue is very simplified. It is assumed a priori that in each case a green roof provides compensation to half the area (50%) occupied by the building. There is no reliable indicator in applications adapted to local conditions allowing to determine the impact of green roofs on the environment, taking into account, for example, the thickness of the applied construction layer (e.g. substrates), the amount of retained rain water (evapotranspiration, infiltration and surface runoff), the type of introduced vegetation (e.g. intensive or extensive roof) or location of the building in relation to surrounding areas with defined land use (e.g. urban or open areas).

The Polish legal instruments have not taken into account the relationship between the environmental compensation the green roof could provide and its "biological capacity", as it happens in other European countries and beyond, such as Biotopflächenfaktor (Berlin), Green Area Factor (Malmö), Seattle Green Factor, Green Plot Ratio or Greenery Provision (Singapore).

Another related barrier is an insufficient level of research on the functioning of green roofs in Poland among others in fields such as architecture, landscape architecture, urban design, statics and construction of buildings, materials science, ecology, climatology, environmental protection and others. This is caused partly by the restricted access to already completed green roofs, which could be used as a kind of research polygon to conduct monitoring and observations. Only recently have some Polish universities and research institutes begun the first research projects and scientific work contributed to the functioning of green roofs under domestic conditions. For example, since 2009, such studies have been conducted on research posts installed on the roof of the Centre for Science and Educational Sciences of the University of Wrocław. One purpose of the study is to determine the possibility of the retention of green roofs and their effect on runoff delay and reducing peak wave outflow during precipitation (Burszta-Adamiak 2010).

6. EDUCATION ABOUT OF GREEN ROOFS IN POLAND

Education on issues relating to green roofs in Poland is generally carried out at universities conducting landscape architecture study programs. The landscape architecture program at Warsaw University of Life Sciences - SGGW is the oldest of its kind in Poland, with origins in the 1930s. The program of studies carried out at WULS - SGGW takes into account the growing environmental, economic and social importance of green roofs in contemporary cities. Graduates in the field of landscape architecture are increasingly involved in the design and construction of this kind of green infrastructure. Therefore, since 2008, mandatory classes related to the basics of green roofs construction at WULS – SGGW are held at the first stage of landscape architecture studies (BSc). To cooperate with these classes, representatives of companies engaged in the practice of green roofs are invited. So, besides the theory, numerous comments of a practical nature are passed on. The field part of classes is a tour, during which students view already implemented green roofs or those under construction around Warsaw. Applied design solutions, both the correct ones and those that are doubtful, are discussed (Łukaszkiewicz 2010).

The second degree (MA) of landscape architecture at WULS - SGGW offers students a subject (30 hours of lectures and classes) devoted exclusively to green roof aspects. The aim of the classes is to broaden students' knowledge in the fields of design, construction and maintenance of green roofs. Participants become familiar with the practical aspects of the use of building materials and plants and implementing technology in technical, spatial and legal contexts.

In addition, dissertations about green roofs have been awarded for many years in the landscape architecture department at WULS - SGGW. The first thesis devoted to this subject was done in 1978. Since then, nearly 40 diplomas were awarded. The practice shows that dissertations on this topic are prepared in three basic categories: guidelines for the design of green roofs, green roof projects, and the evaluation of the functioning of green roofing solutions. Theses of the first category include the establishment of guidelines for the design of green roofs in specific locations, such as residential areas, underground infrastructure, or vertical architectural surfaces. The second category includes design work, presenting ideas and detailed solutions of green roofs on specific objects. Theses grouped in the third category include qualitative and technological assessments of existing green roofs, as well as the evaluation and comparison of applied vegetation on roofs and assess the functioning of specific green roof systems in an urban environment.

In Poland, education in the field of green roofs outside universities is also carried out by other entities, including numerous associations and

Intensive green roof, Golden Terraces shopping center in Warsaw, photo P. Kozuchowski.

foundations who take notice of green roofs among other issues concerning urban planning and greenery management. Their offer is addressed to professionals from various industries (conferences, symposia, etc.) and also to society (picnics, festivals, etc.).

7. POLICIES OF POLISH CITIES TOWARDS IMPLEMENTATION OF GREEN ROOFS

Green roofs, as an important part of green infrastructure, among other aspects, contribute to mitigating the adverse effects of climate change. Local authorities in Poland do not have uniform rules and procedures for raising funds and systematic introduction of green roofs in urban areas. There are only general rules on liability of local governments for green spaces, tree stands and woodlands.

Policies of Polish cities devoted to green roofs should be conducted especially in two very important contemporary aspects:

- The management of rainwater in urban areas

- The reduction of energy consumption and CO_2 emissions

Storm water management in Polish municipalities still does not sufficiently comply with the principles of sustainable development (Wójcikowska 2009). Our country has a negative water balance, because outflows of water are not offset by income (e.g. Kundzewicz 2001, Rakiel-Czarnecka 2004). The lowest annual rainfall occurs in the lowlands, in the central part of Poland and now stands at 450 - 550 mm. Only two European countries, Belgium and Malta, have water resources per capita lower than Poland (e.g. Aquadocinter 2001).

In Poland, elimination of rainwater, especially an increase in the possibility of retention and reduction of impervious surface runoff, is of fundamental importance for the improvement of unfavorable water balance and adverse weather events (droughts, floods, urban heat islands, etc.). In Europe, the establishment of green roofs is part of a strategy to tackle these problems (e.g. Edel 2009). This is closely related to the charging system applied in many European cities, for the discharge of rainwater from impervious surfaces to the municipal sewer system. Depending on the method of calculating the amount of tax on rainwater discharge, green roofs are treated as a factor in reducing losses and loads on the sewer system (the outflows, increased retention distributed) and allow for a reduction of fees. This is a clear incentive for the public to implement this green infrastructure.

In Poland, this is still a new issue arousing controversy, well known only to a narrow group of specialists. Despite a statutory obligation, any widespread use of fees for drainage of rainwater is practiced. Water companies are obliged to determine the quantity of storm-water discharged from urban areas. They often use different methods for estimating the amount of discharged water (e.g. Burszta-Adamiak 2009). Green roofs, which have important implications for the distributed retention in cities, are usually omitted from these calculations. So far, few Polish cities have chosen to implement the fees for drainage of rainwater (e.g. Piła, Gniezno, Siedlce, Kielce, Tarnów, Opole and some others). Therefore, in Polish cities the strategy for implementing green roofs should be combined with social information campaigns concerning the management of rainwater.

The implementation of green roofs by local authorities in Poland, beyond improving the management of rainwater, should become one of the measures aimed at reducing CO_2 emissions, mitigating the effect of urban heat islands, increasing the biodiversity of urban areas and improving the aesthetics of the environment. Local authorities play a key role in achieving the EU's strategy for the energy and climate protection. The Covenant of Mayors is a European initiative in which cities, towns and regions voluntarily agree to limit their carbon dioxide (CO_2) emissions by at least 20% by 2020. Fulfillment of this formal commitment requires the development of a “Sustainable Energy Action Plan” – SEAP – by each of the participants (Bertoldi et al. 2010).

Concerning the implementation of green roofs by SEAP, Polish municipalities may perform at least two types of actions: the construction of green roofs on its own buildings (investment activity, providing direct effect of emission reductions) and campaigns to promote the idea of green roofs among residents (soft effect, giving an indirect effect of emission reductions). The first step could be an inventory of municipal capacity to establish green roofs: an estimation of the total available space and identification of possible achievable results. The next step would then be a possible choice of municipal buildings for which a preliminary draft would be developed to adapt the green roof, the implementation of which should be included in the SEAP (e.g. Płonka 2013). Since 2009, over 4,500 European cities and municipalities have joined the Covenant of Mayors, which means that nearly 170 million people are actively involved in the implementation of the commitments. As of today there are 35 Polish cities and municipalities among them, e.g. Bielsko-Biała, Bydgoszcz, Częstochowa, Dąbrowa Górnicza, Ełk, Niepołomice, Władysławowo and others.

8. SUMMARY AND CONCLUSIONS

This chapter presents the key issues concerning the development of green roofs in Poland within context of the quality of urban landscape and sustainable architecture.

Green roofs have entered the canon of Polish architecture, as seen in many examples of office buildings and a number of other public and commercial investments builtsince the 1990s. The increase of the housing development is also associated with green roof surfaces. However, the cost of green roof installation in Poland still stands relatively high (compared to Germany, for example) due to a rather low (respectively) level of competitiveness and competence within the sector.

Green roofs are already widely used in Poland, however, they are mostly intensive with a slowly growing share of extensive applications. In Poland, simple technology such as extensive greening is still marginally practiced by both planners and gardeners, as well as product suppliers. Though in principle much more expensive, roof gardens tend to be readily measured and carried out, so on many occasions the costs involved in the benches, lamps, fountains, playgrounds, alleys and vegetation is much higher than the cost of technical materials used for the build-up. The situation in the market also means the vast majority of green roofs are performed using inverted roof technology systems.

The notion of green roofs is not expressly mentioned in Polish law. It specifies that the green roof could provide 50% of environmental compensation for a biologically active area occupied under the building. Due to application of this green infrastructure, developers can build over larger areas of building plots. Examples of the investment of the entire country suggest that green roofs are becoming the technology for which demand is constantly growing and the activity of industry companies is affected.

Among factors limiting the development of green roofs in Poland are:

• The insufficient level of education and public awareness of the functioning of green roofs

• The lack of adequate legislation implementing reduction of fees and subsidies that could motivate investors to make of green roofs (especially on flat roofs)

• The lack of separate standards and guidelines related to the design of green roofs adapted to Polish conditions (the industry guidelines for green roofs are not available, so some of the professionals refer to the FLL guidelines but even the knowledge of these standards is rather low)

• The Polish legal instruments have not taken into account the relationship between the environmental compensation the green roof could provide and its "biological capacity"

The education on issues relating to green roofs in Poland is generally carried out at universities conducting landscape architecture study programs such as the oldest of its kind in Poland at the Warsaw University of Life Sciences - SGGW. Mandatory classes related to the basics of green roof construction are held at the first stage of landscape architecture studies (BSc) as well as in the second degree program (MA). In addition, dissertations about green roofs are promoted. Outside universities, other entities including numerous associations and foundations, take notice of green roofs among other issues. Their offer is addressed to professionals as well as to society.

Increasing urbanization in Poland results in problems of the extensive waterways and shows the growing need for offsetting the storm water management to improve the sewer systems which are primarily combined systems. In recent years the seasonal floods have tended to cause severe damage across the country, especially in settlements and infrastructure built in urban areas and along rivers. That's why policies of Polish cities devoted to green roofs should be conducted especially in two very important contemporary aspects:

• The management of rainwater in urban areas

- The reduction of energy consumption and CO_2 emissions

In the Polish cities, strategies for implementing green roofs should be combined with social information campaigns concerning the management of rainwater. This is closely related to the charging system applied in many European cities for discharging rainwater from impervious surfaces to the municipal sewer system. In Poland, this is still a new issue, arousing controversy and well known only to a narrow group of specialists.

The implementation of green roofs by local authorities in Poland, beyond improving the management of rainwater, should become one of the measures aimed at reducing CO_2 emissions, mitigating the effect of urban heat islands, increasing the biodiversity of urban areas and improving aesthetics of the environment. Polish municipalities (local authorities) could include the implementation of green roofs in a "Sustainable Energy Action Plan" - SEAP - as a fulfillment of a voluntarily agreement to limit carbon dioxide (CO_2) emissions in the European initiative - the Covenant of Mayors.

The green roof industry in Poland is still young and inexperienced. Yet, increasing real estate prices combined with the legal measures of natural compensation add to its valuable potential. On the eve of the implementation of storm water fees and in search of solutions to the problems of increasing urban density, green roofs should become a vital element of contemporary architecture in Poland.

Espace Aquatique de Morzine France Source: Greenroofs.com; Photo Courtesy: Le Prieuré Vegetal i.D.®

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CHAPTER 4

GREEN ROOFS AND GREEN CITIES IN LATIN AMERICA: DEVELOPMENT OF THE SECTOR AND ECONOMIC, SOCIAL AND POLITICAL ASPECTS

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INTRODUCTION

Cities around the world are developing in a biocidal way, rambling through nature without any attempt of integration. No different from the rest of the world, Latin American cities are growing in a disproportional and non-planned way, disregarding and disrupting local ecosystems. The loss of green spaces in urban areas, and the increment of impermeable sites challenge local climate and human wellbeing, directly affecting the quality of life of its inhabitants and our biodiversity, which is increasingly shrinking at alarming rates.

Biophilic urban green infrastructure is developing in a way that can mimic nature, preserve it and promote it. The need for more natural cities is rising all over the planet and in the minds of a more conscious humanity. Nevertheless, deep challenges are ahead, like mitigating the effects of climate change; water, energy and food scarcity, big drying periods interpolated with violent storms, floods, and the intensification of pollution and sanitation problems.

The need for investment in green infrastructure and its technologies in Latin America from public and private sectors is evident, although still incipient. Efforts have been made and its acceptance is increasing at a positive rate. Among green technologies, green roofs have grown as the main core of green infrastructure in Latin America.

The goal of this chapter consists of presenting the evolution of green infrastructure, especially green roofs, in Latin America, emphasizing on its economic, social and political aspects. The chapter is divided in two topics and their sub-topics, followed by their conclusions. First, we focus on the development of social, economic and political sectors. The second part represents some examples of Latin American cities that are developing towards green infrastructure, transforming into true green cities. As a conclusion, the chapter will demonstrate the perspective and potential of green infrastructure, especially green roofs in the region, and consider the broad aspects of this paper.

METHODOLOGY

Deductive approaches were used in the following paper, starting from universal principles in order to reach the smaller premises. Bibliographic research techniques are used along with indirect documentation.

1. GREEN ROOFS IN LATIN AMERICA

1.1 From isolated works to the emergence of an industry

The idea of green infrastructure is very recent globally and in Latin America this is no different.

Green roofs, the most popular and well-known technology of green infrastructure, have existed in the region for decades. However, only recently has it started to be adopted and explored on a large scale, in commercial, residential and industrial projects.

One of the first Latin American green roofs was designed in 1936 by Roberto Burle Marx for the Gustavo Capanema Palace. The headquarters

Green roof project by Roberto Burle Marx, city of Rio de Janeiro, Brazil. http://www.adeanewsletter.com/o-telhado-verde-de-le-corbusier/.

Green roof constructed on top of the Matarazzo Building, city of São Paulo, Brazil. http://www.flickr.com/photos/twiga_swala/3637199840/.

Green roof in the city of Rio de Janeiro, Brazil. http://ecotelhado.com.

of the Ministry of Education, located in the city of Rio de Janeiro, got constructed a few years later[1].

Meanwhile, another green roof was constructed in the Matarazzo building, the City Hall of São Paulo, also in Brazil. From then until the early 2000s, some individual projects were elaborated upon. However, only in the middle of the last decade has it gained the commercial, industrial and political attention it has always deserved, considering its importance to the urban environment as well as the prominence given to it for the purpose of obtaining certifications of sustainable buildings as LEED and AQUA, among others.

From the mid-2000s, specialized companies began to emerge when the concepts of green roofs and green infrastructure started to become popular within the region. Its great success and interest generated with media and consumers, has not only resulted in the expansion of green roofs, but also other green infrastructure products such as vertical gardens, permeable pavements, rain gardens and integrated systems allowed to manage and recycle the wastewater produced in buildings.

The development of this industry in Latin America boosted the emergence of local academic studies, techniques and the benefits of green roofs. Supported by regional and international universities for the relatively good economic response provided by the companies and its positive landscape aesthetics, technology such as green infrastructure began to generate interest from the Latin American public sector. Thus, an institutional action by this sector would be fundamental among the government and the community.

1.2 Green roofs in Latin America: The water dilemma

Green roofs are a common need for every urban region in the world because of their multiples benefits and their attractive aesthetics convincing citizens to be closer to nature. They purify the urban air by retaining carbon dioxide and suspended particles, regenerate local biodiversity, increase green areas and urban humidity, decrease the urban heat island effect and promote social integration in open spaces, among others benefits.

However, contradictors argue that living roofs are not sustainable especially in warm regions, due to the necessity or use of water for appropriate irrigation. Indeed, various populated areas in Latin America are located in hot regions, and the need for irrigation of intensive green roofs is real. There are a lot of alternatives to save or re-use water with other common principles like selecting more resilient species. Nevertheless, many of these resilient species are exotic and are not able to promote local biodiversity. The industry needs to be careful and advance a lot of research because solving one problem can lead to new obstacles.

Green roof in the city of Niterói, Rio de Janeiro, Brazil. http://www.aecweb.com.br/emp/cont/m/sistemas-de-telhados-vivos-criam-e-mantem-o-verde-nos-grandes-centros-urbanos_15177_2757.

Basic sanitation is among the biggest problems in Latin America. The majority of cities in the region do not have proper infrastructure, the result of which is an increase in water contamination. So, it is fair to think that, in the context described above, green roof techniques for hot climates must have special concerns regarding the water used in irrigation systems, such as the quality of the water. It is also important to use green roofs to promote local biodiversity and not exotic plants in order to restore as much of the original regional flora and fauna as possible.

Hence, it is important that Latin American green roofs are designed with retention water tanks below their soil. A larger capacity of water retention under the systems will have positive effects on the green roof and its plants due to its hydric autonomy. With an appropriate water reserve, the green roof system will be able to maintain any kind of plant, specially the native ones.

Latin American green infrastructure companies have been working on solutions for the doubts on water use and basic sanitation problems. One of them, Ecotelhado, from Brazil, has developed an integrated system which is able to reuse and recycle rain and wastewater by using combined green infrastructure technologies like green roofs (endowed with big water retention tanks), vertical gardens and permeable pavements, among others. It is an alternative created to fight the Latin American problems of using potable water in irrigation systems, as well as problems related to basic sanitation and water pollution by solid organic waste discarded from buildings in the region.

Therefore, the water dilemma for green roofs in Latin America, as in any region of high temperature around the world, is the need of systems endowed with appropriate water reserves to promote hydric autonomy for plants. If possible, in order to biologically fight the local problem of basic sanitation, a system able to clean, reuse and recycle rain and wastewater is even better for the region.

1.3 Environmental, political, social and economic activism along with the government and community

Considering all aspects of green roofs and other green infrastructure technologies, not only economic but also social and environmental, a more activist role, not corporatist, proved to be more suitable in some cases.

The Asociación Mexicana para la Naturación de Azoteas (AMENA) was founded in 2005 in order to investigate, inform and promote the economic, social and environmental benefits of green infrastructure.

In Brazil in 2009 the Associação Telhados Verdes para Cidades Saudáveis was founded. Later it was named the Associação Telhado Verde Brasil, and then, following World Green Infrastructure Network, WGIN (which previously focused specifically on green roofs), in order to expand its scope of action, it was named the Associação Tecnologia Verde Brasil (Brazil Green Technology Association, ATVerdeBrasil). It then began to promote green roofs and other green infrastructure technologies such as vertical gardens, permeable pavement, rain gardens, and pluvial and wastewater reuse and recycling systems, among others. The institution now also promotes subjects as urban agriculture, the use of renewable energies, bicycle use as means of everyday transportation, and protection of urban environmental preservation areas, among others.

In Colombia, Recive (Red Colombiana de Infraestructura Vegetada) was founded in 2009. It represents the country along with WGIN and plays a very important role in the development of the sector in the country, especially in its capital of Bogota.

In 2011, Chile's green infrastructure companies founded the Achive (Asociación Chilena de Infraestructura Vegetada). The institution works along with the public and private sectors in order to regulate and promote green infrastructure technologies such as green roofs.

The mobilization of civil society throughout the region has been essential to spreading the idea of green roofs, especially along with the government, as seen with other green infrastructure issues. Rules and drafts of rules have begun to be presented in several cities that require the installation of green roofs in new buildings, present vegetated roofs as an alternative to compensate for construction over part of the necessarily permeable land area, or are related to tax incentives and public sustainable certifications. Moreover, plans that aim to promote green infrastructure technologies and practices have been presented, as will be seen later in this paper.

1.4 Green infrastructure public policies: Latin American current panorama

Currently, there are no national public policies in Latin America that seek to specifically promote green roofs and green infrastructure as a whole. However, there are rules and tools, though not necessarily national, which indirectly stimulate such actions in states and cities through the region.

In Brazil, for example, there is a main guideline, the Federal Law n. 12.187/2010, which created the National Policy on Climate Change. Among the instruments proposed therein, the National Climate Fund deserves a highlight. Regulated by the federal decree n. 7343/2010, it was created to finance and stimulate actions and projects capable of combating climate change, which is directly related to the benefits of green infrastructure technologies, such as green roofs. Regionally, the Environmental Urban Director Plan (Municipal rule n. 434/1999) of the city of Porto Alegre foresees green roofs and permeable pavement as an alternative to partial compensation of permeable land areas. The city of Rio de Janeiro has created a public sustainablility certificate, the Qualiverde

(Municipal Decree n. 35.745/2012), which promotes green roofs, vertical gardens, permeable pavements and other green infrastructure technologies. Goiania, the capital of the state of Goiás, has a rule (rule n. 245/2012) that aids the development of green infrastructure suchas green roofs by tax incentives. Other Brazilian cities also operate in the same way.

In Argentina, some cities have joined a network called the Argentine Cities Network against Climate Changes. This is a public tool to coordinate and promote local environmental public policies in order to fight against climate changes effects. Consequently, green infrastructure projects and policies will certainly be gained. The city of Buenos Aires edited the Green Roof Law (n. 4428/2012), which aims to use tax incentives to private properties to promote this green infrastructure technology.

Furthermore, in the "South Cone" zone, Uruguay has their Sustainable Development and Territorial Ordainment Rule (rule n. 18.308/2008), which aims to promote local green infrastructure, and is focused on integrating people with each other and with nature.

Guatemala also has a public policy for climate change (Decree n. 07/2013), which has the potential to develop green infrastructure over there. In the same way, Mexico also has theirs; the General Rule for Climate Changes.

Beyond these examples of environmental public policies, there are others that promote green infrastructure, as will be seen in the next topic of this chapter.

2. GREEN CITIES IN LATIN AMERICA

Lots of Latin American cities have started their investment in green infrastructure by the public or private sectors and, consequently, in green roofs. There are some examples of these methods in addition to the ones that will be should be shown in this paper: Curitiba and Porto Alegre, from Brazil; Santiago, Chile; La Paz, Bolivia; and Bogotá, Colombia. These cities, despite their environmental, social and economic urban problems, which are unfortunately common for the region, have the potential to become "green cities", even though this will be a long journey.

2.1 Curitiba, Brazil

As the capital of the state of Paraná, Brazil, the city of Curitiba is known as the greenest Brazilian city. This is a reference to biodiversity conservation allied to urban planning integrated

Barigui Park, Curitiba, Paraná, Brazil. http://www.opengreenmap.org/pt-br/greenmap/mapa-verde-curitiba/parque-barigui-6327.

Green roof installed on a factory in the city of Fazenda Rio Grande, located in the Curitiba metropolitan zone. http://ecotelhado.com.

Marinha do Brasil Park, in Porto Alegre, Rio Grande do Sul, Brazil. http://www.exotics.com.br/blog/wp-.

with public transportation, waste recycling and green area preservation. Beautiful public green areas are common views through the city, such as the Barigui Park in the middle of town.

The city has an Environmental Control and Sustainable Development Municipal Plan, called BIOCIDADE. This was edited in 2008 and focuses on biodiversity conservation and preservation, such as urban quality of life, and foresees some actions that promote green infrastructure, such as urban forestry with native trees, urban agriculture and legislation to promote green areas in private properties, among other actions[2].

Despite all the green spread throughout the city, green roofs and other green infrastructure technologies are still incipient. A few small isolated projects have been executed. However, a draft of a rule that aims to require or encourage the installation of green roofs in the city has been discussed, and based on the spirit of it people and its Environmental Control and Sustainable Development Municipal Plan, it is likely that Curitiba will soon become a city covered by green roofs.

2.2 Porto Alegre, Brazil

Porto Alegre is the Capital of Brazil's southernmost state, Rio Grande do Sul. With a population of 1.467.823 people[3], located on the waterside of Lake Guaíba, it is one of the most forested cities in the country[4]. Big green areas, such as the urban parks Marinha do Brasil and Redenção, or the Bone's Hill, are important components of the green spread throughout the city.

Green roof in the downtown of the city of Porto Alegre, Brazil. http://ecotelhado.com.

Green roof on top of the Cardenalicio Palace, in Bogota, Colombia. http://www.ecotelhado.com.co.

Porto Alegre, despite its green public areas, does not have either a climate change policy or a green infrastructure one. However, it is one of the most advanced Brazilian green roof cities, proportionally speaking, with more than 35.000 m² installed.

The main reason for that is the municipal Environmental Urban Development Director Plan (municipal rule n. 434/1999), which has promoted, green roofs as an alternative to make up for the use of permeable land areas since 2007.

Green roof in Bogota, Colombia. http://www.groncol.com/.

2.3 Bogota, Colombia

Encircled by mountains and concomitantly seen by inhabitants as dynamic, chaotic and green, Bogota, the capital of Colombia, is the most populous city in this Andean country, with 7,363,782 inhabitants[5]. It is the largest Colombian city in land area, is still one of the biggest in Latin America, and figures among the 30 largest cities in the world. In the past, at a time when higher level education was rare in the continent, Bogota was called "The Athens of South America" because of the deeply cultural influence in the region with many universities and libraries[6].

In the area of green infrastructure, the city has a Territorial Organization Plan Since 2001, the text has defines that ecological infrastructure is the key element, and it most recent edition from 2013 reserves a special chapter for the issue. Although the regional investments in green infrastructure technologies are still incipient, in the case of green roofs, it is getting increasingly larger.

2.4 La Paz, Bolivia

Set in a "bowl" surrounded by the high mountains of the "altiplano" where the Andes are at their widest, the city of La Paz, the capital "de facto" of Bolivia (constitutionally speaking, the capital is Sucre), is located at a height of more than 3,600 m above sea level. The landscape is totally unmistakable. It is the second largest city of Bolivia behind Santa Cruz de La Sierra, and the population is almost 850.000 inhabitants [7].

Green roofs in La Paz and Bolivia, in general, as with other green infrastructure projects and technologies, are still incipient. However, IMPLAN (La Paz Municipal Institute of Urban Planning), a green infrastructure municipal plan proposition for the main Bolivian city was presented in 2012 during the Urban Forum of Green Cabo,. It focuses on connecting the green areas of La Paz, and on optimizing solutions for water, mobility, biodiversity and public space problems[8]. Based on this, green roofs will consequently be promoted. The idea, therefore, is turning La Paz into a green city.

Green roof in La Paz, Bolivia. http://www.skyscrapercity.com/showthread.php?t=1588836&langid=5.

Beyond that, it is important to mention the Urban Central Park from La Paz, a spread out urban green area that, despite being divided by streets and avenues, is connected by bridges in the middle of the city.

Urban Central Park, La Paz, Bolivia. Picture by KUSEVIC, Pablo, 2013.

2.5 Santiago, Chile

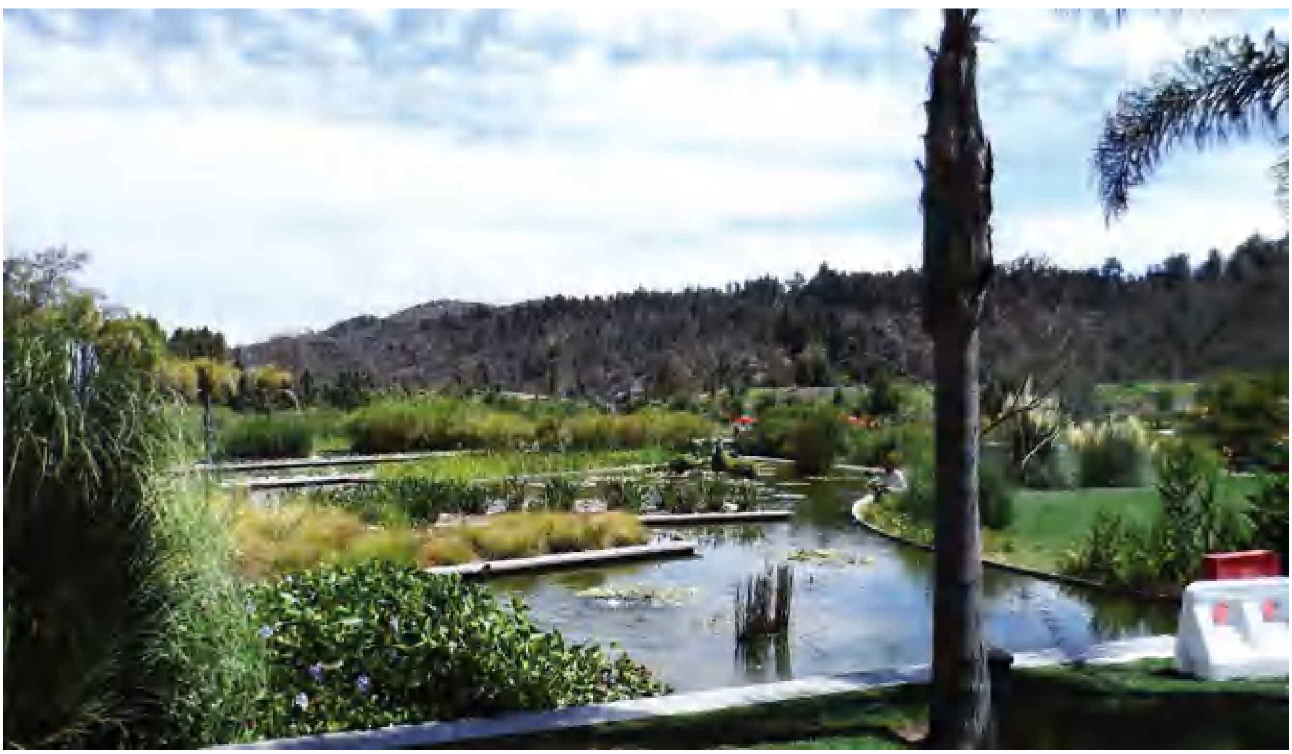
The capital of the best ranked Latin American country in the United Nations Human Development Index (HDI)[9], Santiago, the largest city of Chile with 200.792 inhabitants, is considered a place of few green public spaces. In order to change this scenario, new parks have been recently created. For example, the Ciudad Bicentenario Park opened in 2011 and is considered an example of green infrastructure space. Furthermore, its regional metropolitan government has presented a project called the Green Metropolitan Area Plan for Santiago[10], a big document that has the potential to turn Santiago into a green city according to green infrastructure parameters.

Based on the same need of green space that exists in Santiago in general, the interest in green roofs is expanding, and buildings with tops covered by them have become more common. Certainly, the development of green infrastructure public projects and policies will benefit the promotion of this green technology.

3. CONCLUSIONS

Green infrastructure and its technologies, such as green roofs, are still in the beginning stages in Latin America, and considerations of all the potential development that the sector deserves are underway. However, the challenges coming from climate change effects, the local need for more public and private green areas and the problems related to energy demands and deficient urban basic sanitation force the concerns about fighting these problems.

Because of this, important steps have to be taken. The rise and development of corporative and, principally, activist green infrastructure associations concerned about climate change has revealed that public policies need to be discussed. Associations already exist and the need for green alternatives to improve the quality of urban life by improving the environment and it natural cycles, suggests that the expansion of green infrastructure such as green roofs throughout the region is likely .



Green roof in Santiago, Chile. http://verdeactivo.cl.

Technically, it is important to emphasize the water dilemma for green roofs in Latin America: the need for systems endowed with appropriate water retention tanks in order to promote the hydric autonomy of the plants, especially native species. In this way, systems able to clean, reuse and recycle rain and wastewater discarded by buildings and fight the local problem of basic sanitation are seen as a better biophilic solution for the region.

The perspective, therefore, is that soon the Latin American local and national governments will begin to develop and improve specific urban green infrastructure public policies in order to consolidate in a systematic way its principles, objectives, guidelines and instruments. Certainly the region will gradually see its cities changing from gray to green, with its people and its biodiversity gaining an increased quality of life, following the examples discussed above.

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FOOT NOTES

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CHAPTER 5

GREENROOFS & GREENWALLS IN THE NEW MILLENNIUM: THE INFLUENCE OF THE AGE OF TECHNOLOGY THROUGH ONLINE AND SOCIAL MEDIA

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ABSTRACT

Today, more than half of the world's population lives in cities. From the fabled ancient Hanging Gardens of Babylon to five thousand year old earth-sheltered homes constructed by Neolithic communities to the modern aesthetics of Le Corbusier's "New Architecture," integrating nature into the urban fabric has been an important design criteria and highly desirable amenity for city dwellers. The rise of green, eco-friendly agendas continues to proliferate across global industries and boundaries. Building upon innovative environmental concepts, research and design from green construction pioneers of the 20th century and even prior, the dawning of the third millennium ushered in burgeoning ideals and emerging standards on a grand scale for designing mankind's built environment. Environmental awareness and advanced building technologies have resulted in the huge proliferation of green construction across the board.

Accepting our fragile relationship with nature requires a combination of respect and stewardship of natural resources and the land, by the year 2000 the term "sustainability" was widely embraced within the international design industry. Measures to achieve and measure success in eco-friendly architecture were being established by both the public and private sectors with the advent of demanding benchmarking programs including BREEAM, the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) Green Building Rating System™, BCA Green Mark Scheme, the Sustainable Sites Initiative™ (SITES™), the Living Building Challenge(SM), and many more across the globe. As a society we began to realize we have the choice either to regard our planet as a *commodity* - or as a *community* and design *with* nature.

As just one element, greenroofs have fast become green staples of chic sustainability in mainstream architecture and high performance building practices. And greenwalls (both living

walls and green façades), soon followed as the natural progression for covering a structure with living, breathing plants, with the potential to now envelope the entire structure in vegetation: building integrated greenery. Attractive to young and old, both greenroofs and walls present a wide spectrum of environmental benefits and opportunities for Earth's flora, fauna, and human communities – all while pleasing our economic, aesthetic, and psychological sensibilities with a hip environmental sheen.

This chapter presents an overview of how the advancement of greenroof and wall design, construction, and the industry itself has flourished since the turn of our new 21st century with the advent of the widespread use of the Internet, through its innate entrepreneurial spirit, and the continuing rise of information technologies.

I will discuss basic concepts of online information sharing along with a discussion of the benefits of various network media resources and social media outlets. Online applications will illustrate the wide range of possibilities worldwide from websites, blogs, e-magazines and virtual events, followed by how our living architecture community has benefitted from the international exposure, new upcoming trends, and the seemingly endless future connections and opportunities accessible in a truly open market - made possible by the unlimited power of the Internet.

KEY WORDS

Greenroof, greenwall, social media, sustainability, virtual, living architecture, Internet, Web, online

1. INTRODUCTION AND OVERVIEW

Today, more than half of the world's population lives in cities. From the fabled ancient Hanging Gardens of Babylon to five thousand year old earth-sheltered homes constructed by Neolithic

Skara Brae on the Bay of Skaill, Orkney, Scotland, outside house 8 (to the left) occupied from roughly 3180 BCE-2500 BCE. Europe's most complete Neolithic village, Skara Brae gained UNESCO World Heritage Site status as one of four sites making up "The Heart of Neolithic Orkney." © Wknight94 / Wikimedia Commons / CC-BY-SA-3.0 / GFDL.

Planted to represent the local Fraser River, the Vancouver Public Library Central Branch greenroof offers aesthetic as well as ecological benefits; Photo © American Hydrotech.

communities to the modern aesthetics of Le Corbusier's "New Architecture," integrating nature into the urban fabric has been an important design criteria and highly desirable amenity for city dwellers. The rise of green, eco-friendly agendas continues to proliferate across global industries and boundaries. Building upon innovative environmental concepts, research and design from green construction pioneers of the 20th century and even prior, the dawning of the third millennium ushered in burgeoning ideals and emerging standards on a grand scale for designing mankind's built environment. Environmental awareness and advanced building technologies have resulted in the huge proliferation of green construction across the board.

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This chapter in *Green Cities around the World* presents an overview of how the advancement of greenroof and wall design, construction, and the industry itself has flourished since the turn of our new 21st century with the advent of the widespread use of the Internet, through its innate entrepreneurial spirit, and the continuing rise of information technologies.

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2. GREEN CITIES: THE SEARCH FOR HOLISTIC SOLUTIONS INCLUDES SUSTAINABLE LIVING ARCHITECTURE

Current issues of core global environmental concern have been driving this new greater green ideal, with global warming, air and water pollution, over population, and loss of habitat and biodiversity considered major factors contributing to the call for increased environmental design. Our paving of open land and speculative developmental patterns espouse an almost barbaric attitude with the common "slash and burn" clear cutting techniques prevalent among many Third World and our so-called advanced nations. More recently, we have experienced destruction of the land and the potential for numerous polluted environmental effects through highly lucrative but possibly hazardous practices such as "fracking" (hydraulic fracturing), the process of drilling and injecting fluid into the ground at a high pressure in order to fracture shale rocks to release natural gas inside. For example, more than 600 chemicals are mixed with water and sand in fracking solutions (dangersof fracking.com). And rapid global urbanization has demanded energy efficient and environmentally friendly building envelopes and sites on smaller footprints, taking the development up vertically.

The value of green buildings to people and their communities cannot be overemphasized -from our homes, places of business, educational institutions and healthcare facilities to entire metropolises, we benefit financially and through ecological health. In addition to increased asset values and lowering life cycle costs through reduced energy, maintenance, and replacement expenditures, green design and construction enhances well-being with increased occupant health, student and worker productivity, lower stress levels, and overall quality of life (World Green Building Council, 2013). Appreciation for healthy living has never been higher. Hence, the rise of voluntary green rating and certification programs such as LEED® has spread to global levels, for example with the adoption of the World Green Building Council currently with over 90 countries within its network (worldgbc.org).

Living architecture has become a major architectural trend within the environmental design field, exemplifying sustainability in the context of building design. Through holistic design, organic greenroof and greenwall architecture can actually help restore the health of Earth's ecology by mitigating the negative effects of a building's footprint -

somewhat restoring or evoking displaced greenspace. As part of an overall green infrastructure approach, both are extremely viable building components and appropriate tools for addressing urgent urban ecological development issues of air and water quality, stormwater management, and much more. Popularized by E. O. Wilson, the hypothesis that humans have an innate connection with nature and living things, known as biophilia, stems from theories of evolutionary psychology. As such, we therefore can enjoy and relate to plants growing on a roof or wall from a deeper level than just visual appeal, although this aesthetic, too, is a highly regarded benefit. In addition, the practice of biomimicry – the "new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" (Benyus, 1997) – has also influenced today's architects and designers whose nature-inspired work draws wonders and speaks volumes, providing eco-literacy to the public at large.

And while greenroofs and greenwalls are true work horses as they relate to offering their many physical advantages to both the private and public realms, they deliver much more to the urban landscape. The allure of unique eco-chic "vegitecture" cannot be denied. Vibrant avant-garde and exciting cutting edge designs stimulate our senses, push our design boundaries to greater heights, and expand upon the current architectural vernacular. Simply put, building integrated greenery - the incorporation of vegetation onto the structure itself - helps to invest in the protection of our environment by diminishing developmental impact on our health and communities while providing a fresh approach with visually appealing style. Current trends that are influencing the design and green building fields are also captivating the media.

One of the three Grand Rapids Downtown Market Living Walls; a living roof complements the project. Photo © LiveWall ®.

3. THE AGE OF TECHNOLOGY - REVOLUTIONARY INTERNET INFLUENCES ON THE MARKETPLACE

The rise in popularity of vegetated roofs and walls is no doubt due in part to advances in information technology and the rise of multi-media exposure. Beyond the traditional print, radio and even television venues, the power to reach, inform, and influence the masses at all levels of age and socio-political-geographical backgrounds from around the world has never been greater with the advent of the Internet. According to Internet World Stats, by December 31, 2000, the Internet had 360,985,492 users worldwide and by June 30, 2012 the amount had exploded to 2,405,518,376 users. With Asia leading the way with 1,076,681,059 users, followed by Europe (518,512,109), North America (273,785,413), Latin America / Caribbean (254,915,745), Africa (167,335,676), the Middle East (90,000,455), and Oceania / Australia with 24,287,919, this figure represents a 566.4% growth rate (Internet World Stats, 2013). Ecommerce, entertainment, the rapid diffusion of news and events, along with Email, instant messaging, social networking, texting, video calling over Wi-Fi and Skyping, is not only possible, but expected at the touch of a keyboard or mobile devices. Our views of culture, social relationships, and how we interact in the world of e-business have forever changed through electronic media and smart devices. The Internet has altered the way we do business forever - surfing the net has become a way of life around the world.

Screenshot of Satellite Image of the California Academy of Sciences Greenroof from Google Maps.

3.1 Online Media - Creating a Platform for News, Advocacy and Learning

A wide array of publically accessible or membership-based websites offer reporting from the general news media channels to our targeted industry through online information portals, blogs, discussion forums, journals, e-magazines and e-books, databases, not to mention the vast world of social media, ever growing in popularity. And, the innate *visual* nature of growing, moving, living architecture is perfect for video, perhaps the most popular current web-based medium today. Combining these aspects is a new hybrid - the vlog (blog and video). Video then advances us to the subject of true virtual events – individual webinars, workshops, and full-blown conferences held completely on the Web whether streaming live online, pre-recorded, or a combination of the two.

Arguably, the Internet as we know it began to flourish in earnest in the mid 1990's. Online media has created a platform for news, advocacy and learning and is shaping a new economy. As popular as cable and television continue to be, many people now receive their news from the Internet in some way. In fact, an August 2013 report showed that 50% of the U.S. public now cites the Internet (news media and social media) as a main source for national and international news, with younger Americans aged 30-39 coming in at 71% (Pew Research Center, 2013).

A huge number of freely accessible public websites present general news and information

The Chicago City Hall Greenroof; photo © Roofmeadow. Conceived as a demonstration project, part of the City's Urban Heat Island Initiative, test data was collected from monitoring temperature, rainfall, wind speed and direction. This photo emphasizes its biodiverse quality which ranges in thickness between 3 and 9 inches.

to the public-at-large such as Yahoo! News, HuffingtonPost, CNN, Google News, New York Times, Fox News, The Guardian, The Washington Post, and Reuters leading the way. Non-living architecture specific but environmental related websites include the NRDC (National Resources Defense Council), American Rivers, National Geographic Magazine, Greenpeace International, Environmental News Network, Environmental Defense, National Wildlife Federation, Earth Day Network, Earth Hour, World Green Building Council, the U.S. Green Building Council, Sierra Club, English Nature, and more are dedicated to furthering causes of addressing urban population growth, reducing fossil fuels, cleaning our air and water, altering climate change, implementing green building, fostering respect and stewardship of the land, and so much more. Additionally, sites such as PRWeb and PRNewswire are extremely popular venues to promote company press releases on the Internet. And blogs and sites including ArchDaily, designboom®, Dezeen, Architectural Record, ArchitectureWeek, The Dirt from ASLA, Grist, Tree Hugger, Inhabitat, ARCHITECT, and Houzz to name but a few, have become increasingly popular within the ecological architecture and design communities.

Around since the Cold War era, digital and satellite imagery flood the web from all sectors. Photos, maps, and videos tantalize and inform, and we can now see and share our designs on a global scale. It is mesmerizing to see our communities from a bird's eye view with no restrictions. The built environment – including all facades of a building - is now virtually an open book with mapping sites such as Google Maps and MapQuest which allow us to see the unusual perspective at street level and from a bird's-eye view. Open to the public domain, built examples of architecture and landscape architecture are now open to speculation and review offering unparalleled transparency from a design standpoint.

Screenshot of Greenroofs.com Homepage on January 19, 2014.

Combining weather stations and other in-depth monitoring devices with current online technology allows many test or research greenroofs from both the private and public sectors to stream real time performance data from their host websites, such as the Nueva School, Hillside Learning Complex in Hillsborough, CA and the Chicago City Hall. The advent of live webcams perched atop projects, such as found at the American Society of Landscape Architects' headquarters in Washington, D.C. and the Karen Peck Katz Conservation Education Center in Milwaukee, WI, is another example of integrating technology to further inform and illustrate the decidedly visual properties of living roofs and walls. Live data sharing is one trend which will no doubt continue.

3.2 Industry-Specific Websites

Some of the oldest sites online dedicated to greenroofs came from industry manufacturers and suppliers in the mid to late 1990's, for example Optigrün, ReNatur©, Erisco-Bauder, and Roofmeadow (formerly Roofscapes). A handful of early institutional websites on the subject included the FLL - *Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V.* (Research Society for Landscape Development and Landscape Design), the FBB - *Fachvereinigung Bauwerksbegrünung e.V.* (Professional Green Roof Association), and the DDV - *Deutsche Dachgärtner Verband e.V.* (German Roof Gardener Association) in Germany, and the Rooftops and Urban Agriculture by City Farmer Canada's Office of Urban Agriculture in Vancouver, B.C. and the Augustenborg Botanical Roof Garden in Malmö, Sweden. Arguably, the two oldest and most visited English-speaking non-product specific websites targeting greenroofs (and later walls) exclusively are the open source Greenroofs.com, the international greenroof industry's resource and online information portal (of which I am the founder), and the membership-based Green Roofs for Healthy Cities, the North American greenroof association.

While a student of landscape architecture at the University of Georgia, I completed an independent research paper in early 1999 to study greenroof technology as a viable roofing system and appropriate tool for addressing the urgent urban ecological development issues of air and water quality and storm water management. By October of that year the academic Greenroofs.com was launched, dedicated to exploring the ecology of organic greenroof architecture. "Through the power of the Internet I hope to expose this new aesthetic and help create demand for a greenroof market by providing an open exchange of information and creative thought. By sharing and exchanging information, the objective is to promote greenroof interest and development through a dynamic and interactive "living" research document," (Velazquez, 1999). Through the forward-thinking influence of my husband, Aramis, I realized the immense opportunities of a highly targeted website were literally available at the world's fingertips.

In 2003 Greenroofs.com evolved to better reflect the needs and desires of our ever growing readership and was revamped to its current commercial focus an internet news media organization. We inform, promote, and inspire through the interchange of ideas, projects, news, events, research, community and organization updates, and marketing opportunities; exclusives include the *Sky Gardens ~ where cool green meets lofty blue* Blog, contributing editor columns, guest features, and advertiser press releases. Greenroofs.com publishes the Greenroof & Greenwall Directory; the global Greenroof & Greenwall Projects Database, where our goal is to compile a comprehensive body of living architecture projects all at no charge; the Greenroofs and Walls of the World™ 12 Month Wall Calendar which combines two of our most popular destinations, the Projects Database and Upcoming Events; our greenroofs.tv, a video channel devoted to greenroofs and greenwalls; and the GreenroofsTV channel on YouTube where we encourage and manage a loose network of greenroof videographers.

Now in our eighth year, one of our popular series is the yearly Greenroofs.com *Top 10 List of Hot Trends in Greenroof & Greenwall Design* which showcases the important, newsworthy and exciting greenroof and greenwall projects from around the world. Our Design Editor Haven Kiers and I, as Publisher/Editor, inaugurated the series in 2007. Our "Top 10 List" is designed to be an eye catching and fast-paced presentation of case study vignettes representing the selected top ten categories highlighting the very best of what's avant-garde and hot now. On average, Greenroofs.com receives about 7,500 unique visitors per day from 212 countries.

Founded by Steven Peck and Associates, Green Roofs for Healthy Cities (GRHC) evolved from a small consortium of industry companies promoting the marketplace in Canada and the U.S. in 1999 to a not-for-profit 501(c)(6) in 2004 to the vibrant trade association working to increase awareness of the economic, social, and environmental benefits of greenroofs, greenwalls, and other forms of living architecture through education, advocacy, professionalism, and celebrations of excellence. In addition, GRHC's mission is to develop and protect the market by increasing the awareness of the economic, social and environmental benefits. Some of GRHC products and services includes marketing goods and services offered by members; developing consensus on key training and accreditation requirements, in particular for the Green Roof Professional accreditation or GRP; developing and delivering courses such as Green Roofs 101 – 401; gathering data on industry size and composition from corporate members; organizing CitiesAlive, the annual green roof and wall conference and trade show since 2003; collecting and publishing technical data on green roof and wall performance and project, policy, and industry developments in the Living Architecture Monitor™, the association's quarterly magazine; promoting the development of supportive green roof public policies through Green Roof Symposia in partnership with local governments and other stakeholders. In 2012, GRHC published *The Rise of Living Architecture Commemorative Edition* which celebrates the contribution of more than 50 leading experts to the development of the greenroof and wall industry over the past decade. GRHC's membership has also grown tremendously throughout the years since 1999 and established itself as a leader in our industry.

Other current high traffic industry-specific websites can be found from commercial, educational, public, and institutional sectors, for example: LiveRoof, Green Living Technologies, GreenGrid, Roofmeadow, and ZinCo; Penn State University's Center for Green Roof Research, Michigan State University Green Roof Research Program, and The Green Roof Centre; Green Roofs | Heat Island Effect | US EPA, Chicago Green Roofs, Portland Environmental Services: Ecoroof Program; Green Roofs in the District of Columbia | ddoe; and the Augustenborg Botanical Roof Garden, The International Green Roof Association (IGRA), The Roof is Growing! - American Society of Landscape Architects, and the European Federation of Green Roof Associations – EFB, just to name a few.

New Providence Wharf in London boldly stands out with its cascading roof terraces that provide the occupants with green space and a stunning panoramic view of the Thames. Photo © ZinCo.

3.3 E-Business with E-Commerce

With the dawn of the Internet, retail success is no longer dependent on physical stores. Trailblazing electronic commerce websites have flooded the web since 1995 when both Amazon.com and eBay opened their doors to the great ocean of online shopping. With literally thousands of sites offering a huge variety of goods and services, the Chinese giant Alibaba, founded in 1999, is currently the world's largest retail online shopping outlet. According to a 2013 article in *The Economist* based on forecasts from MGI (McKinsey Global Institute), in 2020 the Chinese online market alone will be between $420 billion and $650 billion (*The Economist*, 2013).

Pertaining to our own industry, on an immensely smaller scale are websites such as the Greenroofs.com Marketplace, offering the Greenroof Depot where you can purchase individual products for your commercial and residential projects and the Bookstore offering books, magazines, design guides, conference materials, and calendars. From Green Roofs for Healthy Cities you can buy items in the Green Infrastructure Store including course manuals, conference proceedings, books, and Green Roof Professional manuals.

A new online marketplace opportunity for emerging ventures is crowdfunding, or collaborative funding via the Internet, that can be either donation-based or investment-based. Popular through sites such as Kickstarter, Indiegogo, and Crowdfunder, among others, they have helped to start, fully fund, or at least bring attention to many worthy creative entrepreneurial and socially forward endeavors, and several within the living architecture community. For example, the successful New York City based Brooklyn Grange rooftop farms – with a total of 2.5 acres and producing over 50,000 lbs of organically-grown vegetables each year - was initially started via a Kickstarter

A pioneer in rooftop agriculture, Brooklyn Grange is a 40,000 square foot commercial farm located above a six-story building in the dense urban environment of Queens, New York. Photo © rooflite®, Skyland USA.

venture in 2012; and in 2013 a Kickstarter campaign was launched for the P-Pod by Ponix, based in Manhattan which provides mini-greenhouses of various sizes that work in areas as small as 3 square feet for locally grown micro-gardens.

The evolution of our global economy started with e-business on all levels, and it is extremely important to stay relevant in a highly competitive market by maintaining a strong web presence. As of the end of 2012, 634 million websites were estimated globally with 51 million added during that year (Royal Pingdom, 2013). Any entity in any market without a vibrant website nowadays is simply out of touch and missing out; it is essential in today's business environment as one of the most powerful marketing tools available. And while it may not be of utmost importance for your website to appear on top index pages such as Google, Bing, and Yahoo!, your potential customers need to be able to find you on the top ranked industry websites where they can research products and companies in one place.

3.4 Social Media: Changing the Face of Networking

Public relations encompass broadcasting a company's news, events, and social happenings; through marketing, we educate and communicate the value or the potential of a product or service to interested customers, and ultimately, our strategy is aimed at influencing buyer behavior. Social media, which by its name is socially responsive and interactive, provides the opportunity of sharing information, establishing, and then building upon long term relationships on a very broad scale through this unique form of Internet marketing. Social media is no longer an emerging new world in cyberspace, but an exponentially growing online reality of fantastical proportions. The impact and importance of social media and how it is changing the landscape of both the personal and professional worlds cannot be overstated. The great majority of social networking sites are free, providing tools to promote yourself, your company, and your marketplace as a whole. Facebook (with 1.26 billion users as of December, 2013), LinkedIn (259 million users as of October, 2013, Twitter (500 million total users as of October, 2013), Google+ (540 million monthly active users as of October, 2013), Pinterest (70 million users as of July, 2013), Tumblr (216.3 million monthly visitors as of May, 2013), Flickr (87 million users as of March, 2013), and Instagram (more than 75 million monthly active users as of December, 2013) are just some of the most widespread social networking websites used to create new online business contacts and friendships with people who share similar interests (Jeffries, Smith, and The Associated Press, 2013).

At Greenroofs.com we encourage our readers, clients and industry peers to connect with us through our social media pages. You can join our greenroof and greenwall community by liking our Facebook page, following us on Twitter, linking with us on LinkedIn, share with us on Google+, and subscribing to our GreenroofsTV channel on YouTube and our monthly eNewsletter.

Since it's extremely popular for people to engage with news across multiple social sites, it's important to understand the individual properties and differences of each platform to enhance your social media strategy. The point is to consistently share information within your network which will then broadcast that news item exponentially.

3.5 Video and Video Conferencing Websites

Arriving on the Internet scene in 2005, the video-sharing website YouTube spawned a cadre of filmmakers, both amateur and professional. Bought by Google for $1.65 billion in November 2006, many other platforms have followed suit including Vimeo, Break, Metacafe, Google Video, Yahoo! Video, Hulu, VEVO, DailyMotion, and many more. You can now upload videos on Facebook, and in January 2013 Twitter introduced Vine, a mobile service that allows people to capture and share short looping videos of six seconds or less.

Videographers have embraced the subject of living architecture on many of these sites, and the nature of video brings the concept to life and makes a project real. Greenroofs and walls can be seen and appreciated from a truly multimedia experience.

Many people have created channels for the subject; for example Greenroofs.com launched greenroofs.tv in 2007 and created the GreenroofsTV channel on YouTube in 2008 which currently has our 209 original videos uploaded with a total of 117,563 views. In addition, since we are an open forum, we have taken the time to select and aggregate other pertinent, high quality industry videos by categories through various playlists, opening up the field to potentially thousands of videos.

Video conferencing websites can be used for personal as well as business endeavors. While Skype has gained popularity for its free international voice and video conversations via computer with friends and family, it is also commonly used very economically in the workplace. Other no-cost options are ooVoo, Tinychat, WebcamNow, CamRoll, and Google Hangouts. And with greater degrees of video quality, Google Apps for Business, Citrix's GoToMeeting™ and Cisco's WebEx are just a few of the numerous fee-based platforms on the market for online meetings.

3.6 Virtual Events: Education, Entertainment, and Social Networking

Rather than meeting in a physical location, a virtual event is a gathering of people sharing a common environment on the web. With the convergence of emerging technologies, we now live in a world where any event can be streamed online. A relatively new field, digital conferencing combines all of the elements of information sharing in our new age of technology for the trade and professional association sector: the latest news and research, social learning and instruction, videos, live information streaming, online marketing, and social networking at its finest. Virtual events, including webcasts and webinars as well as full-blown conferences, are important global conversation tools for communicating with employees, partners, peers, customers and prospects. Conference-hosting platforms include INXPO, Adobe Connect, ON24, Intercall, WebEx, 6connex, 3D-VirtualEvents, and Communique Conferencing, among others.

In 2011, Greenroofs.com produced the inaugural *Greenroofs & Walls of the World™ Virtual Summit: Connecting the Planet + Living Architecture: People, Projects & Design*. In 2013, Greenroofs.com presented the second biennial Virtual Summit in partnership with the World Green Infrastructure Network (WGIN). Shining a virtual international spotlight on vegetative roofing and greenwalls integrating technology, multimedia, and the limitless global reach of the Internet, the mission of the Greenroofs & Walls of the World™ Virtual Summit is to inform, share, and create a global social media experience for learning and networking via the power of the Internet. In addition to raising awareness of our market and industry, the Virtual Summit is an interactive platform for the interchange of ideas through a combination of keynote speakers, expert panels, moderated chat sessions with live Q & A (question and answer), on-demand presentations, plus live video, audio, and text chatting at Sponsor Meeting Rooms, Networking Lounges, and the 24-hour Expo Pavilions showcasing vendors and organizations from across the world.

As important as physical conferences are, the proliferation of national and international events makes it impossible to exhibit and attend them all in terms of time and money and a virtual conference offers innumerable advantages over a traditional in-person event.

The following business and social case for the online events industry enhances the conference going experience on a global level without the expense of travel, lodging, shipping, and more; these benefits were offered to participants of the 2013 and 2011 Greenroofs & Walls of the World™ Virtual Summits:

The Greenroofs & Walls of the World™ Virtual Summit: Connecting the Planet + Living Architecture: People, Projects & Design presented by Greenroofs.com in partnership with the World Green Infrastructure Network.

• Individuals and businesses are connected virtually and easily using a multi-dimensional and immersive architecture.

• The Virtual Experience Platform lets each user collaborate privately and publicly with a flexible, “living” social network comprised of attendees, exhibitors and speakers, making new contacts via the Social Media Suite of options.

• Attendees watch video presentations and then interact and participate in Q & A sessions with featured speakers and expert panels.

• Participants listen to world renowned speakers – thinkers and designers – sharing their experiences with world class living “vegitecture” projects, gaining knowledge of lessons learned from immersions into real life case studies and being inspired by visionary architects and designers on the cutting edge of design.

• Participants leisurely roam the live Expo Pavilions on specific days where they chat live, see video presentations and download product literature from manufacturers, suppliers, and professionals.

• Exhibitors can successfully engage hundreds more key project stakeholders with a wide variety of eye catching, interactive tools.

• From a sponsor or exhibitor's standpoint, online events result in actionable target audience intelligence with complete metrics provided to measure ROI - return on investment.

Real time videos as well as pre-recorded videos scheduled live transform a simple speech or PowerPoint presentation into something much more appealing: living, breathing human beings interacting with others on a panel, a one-to one video chat, or with nature atop a roof - anywhere and, through an on-demand feature, at any time in the world. The virtual experience encourages active and open debate of differing points of view and draws highly visible, yet far-flung thinkers and experts who otherwise might not be available to present, drawing more attendees.

One of our 2013 keynote speakers, Aditya Ranade with Lux Research, examined the drivers as well as barriers for growth in the burgeoning market of BIV (building integrated vegetation). He spoke about the amazing amount of development that has occurred over the past 10-15 years in the vegetative roofing industry and the fact that initiatives in policy within the market place are driven by individual cities' particular needs. According to his September 2012 Lux Research report as lead analyst, at present 63 cities across the globe – including Chicago, Toronto, Portland, London, Copenhagen, Tokyo, Singapore, Mexico City, Beijing, Bogotá and Sydney to name just a few outside of trendsetting Germany - have implemented mandates or incentives for vegetated roofs to manage stormwater, clean air pollutants, reduce the urban heat island effect, protect biodiversity, and sequester carbon dioxide. He also stated that greenroofs are a $5.5 billion burgeoning world market, projected to reach $7.7 billion by 2017. Cumulative greenroof installation in 2011 was about 100,000,000 m² and is projected to double to 200,000,000 m². Greenwalls will be a $680 million market by 2017; cumulative greenwall installations will increase 16 times over the next five years with an expected 4,500,000 m² implemented during this time frame (Lux Research, 2012). As proprietary information from Lux Research, this insight and more was only made available to paying Lux Research subscribers and Virtual Summit 2013 attendees.

Screenshot of the 2013 Greenroofs & Walls of the World™ Virtual Summit Homepage.

While virtual meetings cannot replicate the quality of face-to-face meetings, and in fact complement traditional meetings, the virtual trend is growing and here to stay. Virtual knowledge sharing and participation is available to the entire global population at a fraction of the cost of a physical conference - with none of its carbon footprint – but with an incredible opportunity to meet and interact with renowned experts and practitioners. The ability to attract a larger and more varied audience is highly attractive, and with the downturn in the economy, the benefits are many. Virtual events present a forum for information, communication, community building, and

At the heart of the Native Child and Family Services of Toronto community greenroof is the Healing Lodge. Photo © Bioroof Systems.

collective understanding as well as lead and sales generation and extended brand exposure.

Increasingly, people live on the web and are comfortable with it. Virtual conferencing is perceived as a new and cutting-edge way to access information and businesses that participate in virtual events are seen as being progressive by attendees, who benefit from their association with this. The Greenroofs & Walls of the World™ Virtual Summit ponders the question, "Imagine a world of green: What are we doing to advance living architecture?" As in the case of worldwide Internet users, the potential for future exponential growth in terms of attendance is astronomical. According to Market Research Media, virtual events are forecasted to continue at a compound annual growth rate of 56% through 2015, (Trendline Interactive, 2011). The virtual event experience will continue to evolve as an affordable and highly accessible avant-garde platform and conservatively, the Greenroofs & Walls of the World™ Virtual Summit 2015 is expected to more than double its association collaboration, sponsorship and attendance.

4. CONCLUSION - A GREEN, OPEN AND TECHNICAL VISION FOR THE 21ST CENTURY

An unprecedented wave of global urbanization is driving economic and construction transformations. We've come to an important crossroads in how we rebuild our cities and market our goods and services. In our third millennium, the 21st century, environmentally responsible innovation is multi-disciplinary and crosses all boundaries of place, profession, and politics. Do we want to settle for Nature in the City or the City as Nature? Is this possible and is it sustainable? While we ponder these ideas, we can mitigate some of our developmental problems with greenroofs and greenwalls and reap an amazing array of benefits. And, unrestricted accessibility to the Internet represents a complete global democratization of information sharing at its finest.

Since 2000, the business case for green building has been tried and tested with in-depth reporting, scientific monitoring, case studies and success stories. Thanks to the Internet, open data—public information and shared data from private sources, along with trials and tribulations, learning about new and emerging

Located in the historic district of downtown Durham, North Carolina, The Republik Building is home of the national headquarters of Xero Flor America; Photo © Xero Flor America.

ideas and technologies has never been easier. And promoting our growing design and construction industry pertinent for truly regenerative landscapes and buildings has never been more convenient. The business landscape has changed from simple marketing in the local community by having a storefront

and a membership in the regional association to establishing your company on the web and continuing through with SEO (search engine optimization) positioning. For companies, organizations and governments to remain relevant and fully profit from online and social media, our traditional marketplace needs to get up to speed with the technologies of the third millennium and participate in the successful landscape of the Internet.

Keeping on top of social networks can be challenging, but you will be rewarded if you focus efforts in media related to your niche. Jump in the vast world of social media - not only follow your favorites but join in on the discussion on current green technology! Make sure you or someone in your organization is up-to-date with greenroof and greenwall news and shares relevant happenings. Visit favorite websites to learn about new projects, policies and issues. Listen to industry insiders and follow their columns, and send in your feedback about your own experiences – the living architecture community needs the voices of many, not just a few, to be robust, visionary, and push the limits. Commit the time and resources and invest in social media to position your government, institution, company or organization for continued growth; social media strategists would advise that positioning will result in lead generation, referral traffic, and revenue, in addition to company branding and improved brand awareness. Don't let the conversation miss your voice; keep it flowing – how better to do that than via the endless scope of the Internet?

Beauty and ecology can inspire creative and forward-thinking design and development through restorative design. As we continue to make our cities greener and healthier places by designing sustainably, they will become places where people will want to live, play and work and economics will naturally follow. The advantages of living architecture are too many to ignore...Designing with greenroofs and walls is an ideal architectural union of aesthetics, economics, and ecology – yet they are but one element in the palette of the new millennium's ecological designer, governmental policy maker, and corporate social responsibility plan. An integrated design approach is necessary for true sustainability of complete systems and an open source approach to information sharing on the Internet is essential for our continued promotion and growth of the living architecture industry. From Chicago to Mumbai to Santiago, from London to Moscow to Singapore and Sydney and beyond, the allure of a virtual world opens endless possibilities to everyone in all places on Earth.

In part, the current environmental crisis is the result of design failure to consider the health of human neighborhoods or of ecosystems. As practitioners of living architecture, we have a unique opportunity to make the world a better place for all. Embracing the spirit of innovation, let's continue our collective work of the past 15-20 years with bold insights into new ways to design living buildings and collaborate together to promote the industry even further through a beautiful, vibrant, and open online greenroof and greenwall marketplace and community.

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A new Hotel complex in downtown Singapore. It becomes unique by using vegetation on the building in a creative way.
Source: M. Köhler.

ENVIRONMENT SCENARIO

The City of Vancouver, B.C. Olympic and Paralympic. Source: greenroofs.com; Photo Courtesy of Vitaroofs International Inc.

CHAPTER 6

THE POTENTIAL OF GREEN ROOFS TO SUPPORT URBAN BIODIVERSITY

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ABSTRACT

Loss of biodiversity, including loss of ecosystems, species, and genes, has been documented at alarming rates with urbanization identified as one of the most influential causes. Biodiversity in urban areas is now more homogenous across cities and unique specialist species are rare. In the face of enormous habitat changes, initial studies suggest that green roofs have the potential to support greater biodiversity by creating unique habitats, providing ecosystem services and expanding urban corridors. However, the work to date has focused at the species level and the full scope of biodiversity on green roofs has yet to be realized. Recommendations are made in this chapter for encouraging the inclusion of biodiversity at all levels into green roof design and city planning.

KEY WORDS

Biodiversity, conservation, diversity, green infrastructure, green roof, urbanization.

1. BACKGROUND: THE NEED TO CONSERVE BIODIVERSITY IN URBAN AREAS

1.1. Biodiversity

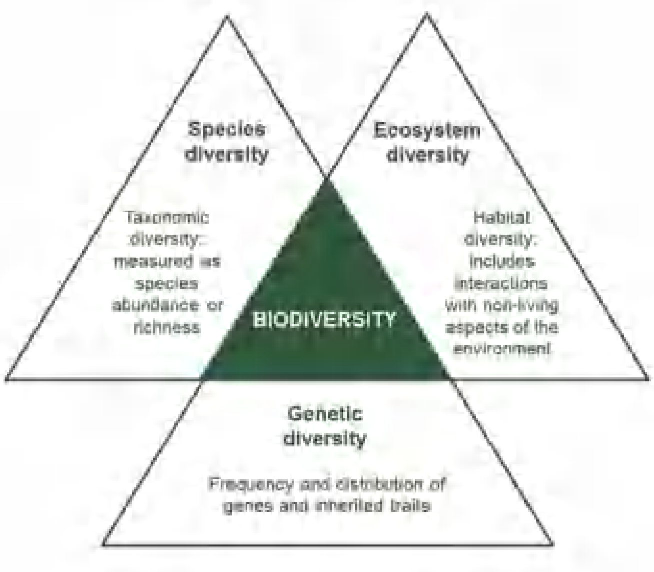
In cities around the world the argument that green roofs enhance urban biodiversity is increasingly being used to attract funding and public support for their construction. However, the term 'biodiversity' is not always used correctly or with the full realization of the complexities encompassing its various measures. In order to encourage more widespread adoption of biodiversity conservation on green roofs, it is first essential to develop a working understanding of all that encompasses biodiversity.

The term biodiversity was used for the first time in 1986 at the National Forum on BioDiversity in Washington, D.C. (Harper & Hawsworth 1994). The term has grown in popularity since then and is now used extensively in academic publications and throughout the general media

(Harper & Hawsworth 1994). In its most simple form, biodiversity is short for biological diversity and includes three biological levels: ecosystems, species and genes (Allaby 2006; Figure 1). Expanded definitions include structure, function, community composition and complex interactions between organisms at all temporal and spatial scales (Savard et al. 2000; Millennium Ecosystem Assessment 2005; Elmqvist et al 2013).

Regardless of definition used, it is important to point out that biodiversity is much more than mere species diversity (Savard et al. 2000) and these terms should not be used interchangeably. Species or taxonomic diversity is often measured as species richness or the abundance in a given area and is only a small part of total biodiversity. Measuring only species diversity omits other critical aspects of biodiversity such as population structure (species evenness) and genetic diversity, both of which contribute to community resiliency. Genetic diversity, in particular, is an often neglected component of biodiversity measurements (Laikre et al. 2010) but is essential for adaptation and long-term species survival. The combination of ecosystem, species and genetic diversity provide human beings with food, clean water and air, operational sanitation, effective methods for managing livestock and agriculture, and security for future crises (Millennium Ecosystem Assessment 2005; Secretariat of the Convention on Biological Diversity 2012). As the global human population grows and the demands on natural resources increase, traditional conservation practices will no longer be adequate to meet and overcome eminent challenges.

FIGURE 1. BIODIVERSITY ENCOMPASSES ALL ASPECTS OF BIOLOGICAL DIVERSITY INCLUDING ECOSYSTEM, SPECIES AND GENETIC DIVERSITY



Conserving the Earth's biological diversity is essential. Because this challenge is complex, the solutions to alleviating the current rate of biodiversity loss must be creative, coordinated and intentional. To this end, the community of architects, engineers, city planners and scientists alike are met with a unique opportunity to leverage future green roof infrastructure to achieve a multitude of goals. A united effort has the potential to enhance the benefits of green roofs to move beyond the standard building efficiency benefits they provide to contribute to and enhance biodiversity within the urban landscape.

1.2. Effects of urbanization on biodiversity

Human activities have contributed to a greater loss of biodiversity on Earth over the past 50 years than at any other time period in human history (Millennium Ecosystem Assessment 2005). Current projections reveal alarming scenarios for increased rates of biodiversity loss around the world (Millennium Ecosystem Assessment 2005). Urbanization has both direct and indirect effects on local, regional and global biodiversity, the largest and most direct being the transformation and loss of natural habitat (Sala et al. 2000; Millennium Ecosystem

This is a nearly 100 year old extensive green roof in Berlin. Source: M. Köhler.

Assessment 2005; Hahs et al. 2009; Gregor et al. 2012; McDonald et al. 2013). Land transformation removes natural vegetation and fragments communities (Güneralp et al. 2013; Müller et al. 2013). Remaining habitat fragments generally have altered microclimate characteristics, such as increased edge effects, changes in disturbance regimes, altered nutrient cycling and perturbations in population dynamics (Hahs et al. 2009; Solecki & Marcotullio 2013). Over the next few decades, land conversion is expected to displace thousands of plant and animal species, including hundreds already on the International Union for Conservation of Nature Endangered or Critically Endangered Lists (Seto et al. 2012). In addition to global species extinctions, many other species will also become endangered and/or locally extinct (extripated).

In addition to the loss of species and habitat, the resulting increase in heterogeneously arranged habitat fragments can disrupt ecological pathways (Müller et al. 2013) such as migration, seed dispersal and gene flow (McDonald et al. 2013). Land use changes also indirectly affect communities by contributing to climate change and urban heat islands (Millennium Ecosystem Assessment 2005; Elmqvist, et al. 2013; Güneralp et al. 2013; Müller et al. 2013; Solecki & Marcotullio 2013). Increased pollution, dominance of invasive species and overexploitation of resources (Millennium Ecosystem Assessment 2005), as well as changes in hydrology and soil biogeochemistry (Güneralp et al. 2013) make urban habitats difficult living environments for many organisms. The combination of the many direct and indirect consequences of urbanization can ultimately decrease the robustness and resiliency of biodiversity worldwide.

Urbanization is projected to expand over the next few decades and pose an intensified threat to biodiversity (McKinney 2002). Compared to 2000, the extent of global urban land cover is projected to increase by up to 185% by 2030 (Secretariat of the Convention on Biological Diversity 2012; Seto et al. 2012). Recent estimates suggest that the number of people living in urban areas globally will double between 2000 and 2030 and urban land area will triple in order to accommodate the high demand for living space (Elmqvist, et al. 2013). This is particularly true in areas considered to have the highest amount of biodiversity (hotspots) and in rapidly developing regions of Asia (Miller & Hobbs 2002; McKinney 2006; Seto et al. 2012; Secretariat of the Convention on Biological Diversity 2012; Güneralp et al. 2013). The opportunity exists now for all nations to incorporate explicit biodiversity conservation goals for novel urban habitats into their future plans.

1.3. Biodiversity in urban landscapes

The Millennium Ecosystem Assessment stresses that the need for conservation of biodiversity must extend beyond nature reserves to include all urban areas (Millennium Ecosystem Assessment 2005). While it is generally known that urbanization affects global biodiversity, only recently have researchers begun to understand the ecological processes that support biodiversity within cities (Millennium Ecosystem Assessment 2005). It is clear that urbanization negatively influences biodiversity by supporting more exotic species and promoting global homogenization of plants and animals. However, cities also harbor distinctly urban habitats, such as green roofs, which may support many species with unique traits.

Globally, cities have experienced high extirpation rates of many plant species (McKinney 2006; Hahs et al. 2009; Duncan et al. 2011). A decrease in native flora in urban habitats can lead to further cascades of species loss for both above and below-ground fauna at local and regional spatial scales (Faeth et al. 2005; Chace & Walsh 2006; Tallamy 2007; Blair & Johnson 2008; Walker et al. 2009; Faeth et al. 2011). For example, the proportion of native plants in urban and suburban tends to be positively correlated with the diversity of native birds (Munyenyembe et al. 1989; French et al. 2005; Chace & Walsh 2006; Burghardt et al. 2009) and insects (Crisp et al. 1998; Burghardt et al. 2009). Pollinating insects can be particularly affected because they may be able to use the pollen and nectar resources more effectively from native plant species than from non-native species (Corbet et al. 2001). In addition to loss of species, loss of genetic diversity within populations can threaten ecosystem resiliency by decreasing the number of species able to survive or recolonize after predation, disease or environmental stressors which cause local extinction events; a problem intensified in highly disturbed urban environments (Olden et al. 2004).

One common trend observed in cities associated with a decreased proportion of native species is a corresponding increase in non-natives (Secretariat of the Convention on Biological Diversity 2012). The high taxonomic richness observed in many cities is inflated by common non-native urban species (McKinney 2006; McKinney 2008; Shochat et al. 2010; Gregor et al. 2012; McDonald et al. 2013), which is the reason urban centers can have higher species richness of plants and animals than surrounding areas (Walker et al. 2009; Faeth et al. 2011). A commonly found set of non-native plant and animal species is now found in cities across the world (for example, the common urban rat, *Rattus norvegicus*, and city pigeon, *Columbia livia*), a pattern called biotic homogenization (Olden et al. 2004). Non-native species richness increases along gradients of both disturbance and urbanization, a trend exacerbated by the globalization of horticultural trade (Müller et al. 2013). In some cities, up to 50% of the species in the urban core or city center are non-native (McKinney 2002; Dunn & Heneghan 2011; McDonald et al. 2013). For example, about a third of all plant species in New York City, Tianjin and Warsaw were found to be non-native and about 50% of plant species were non-native in Dublin, Boston and London (Dunn & Heneghan 2011). Though conservation of common species in cities is important, increased consideration must be given to the species that have or are becoming rare in their natural ranges due to the pressures imposed by urbanization.

2. USING GREEN ROOFS TO ACHIEVE BIODIVERSITY CONSERVATION GOALS

As cities around the world continue to develop technology and infrastructure using environmentally conscious materials and methods (Blaustein 2013), vegetated surfaces have the potential to play an increasingly important role in reconciliation ecology and urban biodiversity conservation (Francis & Lorimer 2011). The principles of reconciliation ecology encourage the design of anthropogenically-dominated landscapes to include considerations for a wide variety of organisms (Rosenzweig 2003). Each year, more urban habitats are designed following these principles, providing a wider variety of ecosystem services and increasing public awareness of biodiversity (Miller 2005). Extensive green roofs, or buildings designed specifically to incorporate a shallow layer of growing media and plants, continue to become more numerous and widely distributed globally (Greenroofs.com 2013). Recent studies in urban ecology suggest that although small habitat patches in cities are subject to extreme environmental stressors, they have the potential to support many elements of biodiversity and should not be overlooked for their conservation value (Miller & Hobbs 2002). Green roofs represent novel habitats in the urban environment and can contribute to the goals of reconciliation ecology by increasing the availability of living space for a variety of organisms (Francis & Lorimer 2011).

2.1. Ecosystem diversity

When green roofs are installed, they create unique habitats on what is often otherwise unutilized space (Francis & Lorimer 2011). It is clear that these novel systems provide a variety of environmental benefits including stormwater capture and retention (Getter & Rowe 2006; Mentens et al. 2006; Carter & Butler 2008; Dunnett, Nagase, Booth, et al. 2008; MacIvor et al. 2011; Schroll et al. 2011; Nagase & Dunnett 2012), pollution abatement (Rowe 2011), thermal insulation of buildings (Getter & Rowe 2006; Carter & Butler 2008; Spala et al. 2008), and mitigation of the urban heat island effect through evaporative cooling. These beneficial aspects of green roofs can indirectly support a variety of organisms in the urban environment.

Green roofs can also directly support organisms by providing unique habitat. Conditions on green roofs are hotter, drier and windier compared to the ground level (Monterusso et al. 2005; Carter & Butler 2008; Nagase & Dunnett 2010; MacIvor et al. 2011). The particular ecosystem on green roofs therefore represents an extreme of local conditions, which can benefit a subset of local species. By supporting small communities, green roofs can serve as an important component of a larger heterogeneous meta-community, increasing the total richness and diversity of species that can use the urban landscape. Some green roofs are now designed to mimic natural habitats which share similar harsh environmental properties in hopes of providing alternatives to in situ conservation of some species (Lundholm 2004; Catalano et al. 2013). This type of design allows green roofs to support unique plant and animal species that would not otherwise be found in the urban environment. If designed with specific ecological goals in mind, green roofs have the potential to support an even greater diversity of local native organisms and processes *ex situ*, thereby slowing biodiversity loss (McKinney 2006).

2.2. Species diversity

Genetic homogenization can threaten ecosystem resiliency by decreasing the number of species able to survive or recolonize after predation, disease, or environmental stressors which cause local extinction events; a problem intensified in highly disturbed urban environments (Olden et al. 2004). In ecology, the widely known theory of island biogeography states that patch (habitat) area often affects species diversity and abundance, with an expectation that smaller patches will have lower taxonomic diversity than larger patches (MacArthur & Wilson 1967). As many green roofs are small compared to city parks or preserved areas, species diversity on roofs is assumed to be low. However, distinctly urban habitats such as preserves, wastelands and vacant lots can significantly contribute to species diversity and richness (Lawson et al. 2008; Müller et al. 2013) and in some cases may even be optimal for population persistence or species survival (McCarthy et al. 2006). In contrast to principles suggested by island biogeography theory, the richness of usable urban habitats has been found to be a more important predictor of bird diversity than patch shape or patch size (Donnelly & Marzluff 2006). Comprehensive studies thus far reveal no correlation between green roof size and species abundance or diversity (Braaker et al. 2013), suggesting that green roofs of all sizes have the potential to sustain high species diversity in cities.

2.3. Genetic diversity

Extinction of species can occur due to a loss of genetic diversity, which tends to be lower in small populations (Spielman et al. 2004). Genetic diversity can be particularly important to species on green roofs, where environmental pressures can be even more extreme than on the ground and local extinction events are likely (Lundholm 2004; Monterusso et al. 2005; Getter & Rowe 2006; MacIvor et al. 2011; Rowe et al. 2012). Low genetic diversity is particularly an issue when green roofs are planted with nursery-grown species, which generally have low genetic diversity and may even be clonal in the case of vegetatively-propagated varieties. Scientific research has yet to demonstrate that plant populations on green roofs possess the genetic diversity needed to respond to severe environmental stressors.

Although few urban gardens and even fewer green roofs are designed with habitat connectivity in mind (Quigley 2011), urban planners could encourage installation of vegetated roofs on buildings near larger green spaces, directly supporting ecological land-use connectivity designs (Colding 2007; Jim 2013). Green roof organisms likely contribute to urban metapopulations, being colonized by individuals from the larger urban population as well as colonizing other nearby areas. With an increased focus on ecology in urban planning, structures could be arranged intentionally to encourage interaction between patches and promote gene flow and migration, thereby increasing habitat resilience and supporting all aspects of urban biodiversity: ecosystem, species, and genetic diversity. Cities that already have expansive green networks, such as Singapore (Tan 2006), could easily incorporate green roofs into their strategies for habitat

connectivity and biodiversity support. Connectivity through gene flow may be a way of preventing genetic decline and promote long-term reproductive success of small fragmented populations (Frankham et al. 2007; González-Varo et al. 2009). Consequently, a well-connected network of urban patches is important to maintain genetic diversity within populations and build community resiliency. Previous studies of urban gardens and backyards have found that small patches can form habitat networks (Elle et al. 2012; Rudd et al. 2002) which allow small populations to possess increased genetic diversity from pollen movement or migration (McIntyre 2000). Patch connectedness can provide stepping-stone habitats for foraging insects which can, in turn, increase total gene flow (Van Rossum & Triest 2012). Increased green roof connectivity could allow a larger variety of organisms with limited mobility to contribute to genetically diverse populations. As the number of green roofs across a city increases, each site has the potential to be part of well-connected urban corridors and metapopulations.

2.4. Challenges

Although there is great potential for green roofs to promote biodiversity, achieving this goal may not be easy. Access to best practices for utilizing green infrastructure to conserve biodiversity is only now becoming more widely available (Sandström et al. 2006; Müller et al. 2013). More importantly, most green roofs are not designed with biodiversity considerations as main objectives (Quigley 2011). While green roofs provide an increase in floral habitat compared to a traditional shingled or tar roof, green roofs are likely to be planted with non-native species (Snodgrass & Snodgrass 2006) which lack genetic diversity and may not provide adequate

An extensive green roof in Berlin. Source: M. Köhler.

resources to support larger faunal communities. Despite increasing local taxonomic plant diversity, green roofs can contribute to biotic homogenization and therefore decrease biodiversity on a global scale when installed without concern for biodiversity. This could be particularly problematic as many green roofs are not taxonomically diverse, often consisting mainly of succulent orpine species (Crassulaceae), or even species exclusively from the genus Sedum (Dunnett & Kingsbury 2004; Snodgrass & Snodgrass 2006). Quickly spreading succulents can contribute to ecological function by facilitating the growth of neighboring forbs with high ecological value (Butler & Orians 2011) and providing quick protection of important soil biota, such as springtails (Collembollans) (Schrader & Böning 2006). Designing roofs dominated by a few plant families may also meet the need to provide an aesthetically-pleasing visual display and ecosystem services such as stormwater retention. However, green roofs planted with a low diversity of species does not necessarily contribute to biodiversity, particularly as many of the "tried and true" species or varieties used globally are rarely locally endemic.

As green roof technology continues to develop, more green roofs are being designed to include a wider variety of native plant species (Butler et al. 2012), echoing the current trend of using more native plants in urban landscaping in general (Müller et al. 2013). Some locally native species may not be appropriate for use on green roofs due to an increased risk of drought, higher wind, and decreased winter soil temperature (Monterusso et al. 2005; Carter & Butler 2008; Nagase & Dunnett 2010; MacIvor et al. 2011). However, despite these limitations, there are numerous species that thrive under natural conditions similar to those encountered on green roofs and can be used to overcome the limitations of monocultures or low-diversity communities. For example, several species from coastal barrens, cliff faces and rock outcrops thrive on green roofs in Canada (Lundholm & Richardson 2010; MacIvor et al. 2011) and Australia (Farrell et al. 2012; Farrell et al. 2013) and many species from dry prairies thrive on green roofs in the central United States (Dvorak & Carroll 2008; Dvorak & Volder 2010; Dvorak et al. 2012). Planting green roofs with plants of high functional, taxonomic and genetic diversity on green roofs is one way to begin achieving biodiversity conservation goals.

Contrary to common assumptions that vegetated roofs adequately support higher trophic levels and all aspects of biodiversity (Oberndorfer et al. 2007), not all instances of plants growing on green roofs ensure a rich and diverse faunal community. Principles of restoration ecology dictate that compositional and functional diversity will not necessarily self-assemble if one simply provides the physical structure (Quigley 2011), a prevalent notion described as the field of dreams myth (i.e. "if you build it, they will come") (Hilderbrand et al. 2005). Furthermore, many building owners expect that their green roof will retain all of the qualities of function and aesthetics over the life-span of the roof, ignoring any natural ecological successional processes. As with other urban ecosystems, floral, faunal, fungal and microbial communities will develop through various stages of ecological successional, particularly because many green roofs are undisturbed habitats (Collins et al. 2000; McKinney 2002). But when these natural processes are suppressed by weeding, watering, addition or movement of certain species, changing out of growing media, or simply by designing the habitat to support a limited number of species (e.g. Sedum), it is unlikely that more complex ecosystems will develop. Creating the correct physical conditions on a green roof which support all aspects of biodiversity is an important first step which must be followed by encouraging colonization by a taxonomically and genetically diverse assemblage of species. Habitat creation is not a simple task but, over time, the dynamic system can change in response to external pressures and the overall community structure can develop into one that helps mitigate biodiversity loss and/or contributes to its conservation.

2.5. Current findings of green roof biodiversity research

Studies regarding green roof biodiversity are now more common and widespread, at least at the level of species diversity. In the absence of intense management, green roof plant diversity can increase over time as species colonize from the surrounding environment (Köhler 2006; Dunnett, Nagase & Hallam 2008; Köhler & Poll 2010; Bates et al. 2013). Increased plant diversity is likely to correspond to an increase in arthropod diversity (McIntyre 2000). When plants with a wide breadth of functional diversity are used, green roofs can provide a higher degree of ecosystem services (Cook-Patton & Bauerle 2012) including better building cooling and insulation (Lundholm et al. 2010), a higher reduction in harmful nitrogenous run-off from roofs (Aitkenhead-Peterson et al. 2010), and greater capture and retention of stormwater (Dunnett, Nagase, Booth, et al. 2008; Anderson et al. 2010; Lundholm et al. 2010; Nagase & Dunnett 2012). Although general urban ecology research suggests that a positive relationship between plant diversity and overall biodiversity exists (Andow 1991; Siemann et al. 1998; Haddad et al. 2001), this relationship has yet to be directly demonstrated on green roofs (Cook-Patton & Bauerle 2012).

In a recent review, Cook-Patton and Bauerle (2012) identified three specific ways in which increasing the structural and functional diversity of plants on green roofs could directly enhance urban biodiversity: (1) the increase in primary productivity of plant species creates a larger food web base, thereby supporting greater faunal abundance and richness; (2) more rare and specialized fauna are supported by unique plant species; and (3) greater temporal availability of food sources supports a wider variety of resource-dependent faunal species, such as pollinators. The first two points highlight opportunities to increase taxonomic diversity while the third highlights contributions to ecosystem functions; in the case of pollination, longer periods of resource availability supports increased foraging and therefore higher genetic diversity. More research is needed to confirm these hypotheses and move beyond knowledge of the mere presence of plant and animal species to a broader, more comprehensive understanding of the ecological processes occurring on green roofs and to determine if patterns observed in natural systems are found in the green roof environment as well.

To begin assessing the current state of biodiversity conservation on green roofs, research regarding faunal taxonomic diversity is now being carried out in many regions. Green roof habitats are used by a variety of mobile organisms including many native and non-native species of birds (Burgess 2004; Baumann 2006; Grant 2006; Fernandez-Canero & Gonzalez-Redondo 2010; Ishimatsu & Ito 2013; Livingroofs.org 2013). For example, in the United Kingdom, green roofs have been incorporated into the London Biodiversity Action Plan to help provide nesting sites for the rare black redstart *Phoenicurus ochruros* which can use the many herbaceous roofs for nesting as well as foraging (Burgess 2004; Gedge & Kadas 2005; Ishimatsu & Ito 2013, Livingroofs.org 2013). Food sources for the black redstart as well as many other bird species include fruits and seeds provided by the diverse vegetation as well as insects and other invertebrates such as mollusks (Kadas 2006). An increase in plant species diversity on green roofs has the potential to provide a temporally-expanded variety of resources to many different foragers.

In addition to vertebrates, a large variety of invertebrates visits and colonizes green roofs (Mecke & Grimm 1997; Mann 1998; MacIvor & Lundholm 2010; Coffman & Waite 2011; Schindler et al. 2011; Braaker et al. 2013; Madre et al. 2013). Though the research is still nascent, evidence suggests that arthropod species abundance and diversity is influenced by abiotic properties of the roof such as substrate depth and structure (Jones 2002). Vegetation strata may also affect patterns of invertebrate colonization (Madre et al. 2013), although it is difficult in some cases to separate the influence

Test installation to learn more about living wall systems. Source: M. Köhler.

of abiotic variables completely from the influence of vegetation (Kaupp et al. 2004). For example, greater invertebrate species diversity has been found on green roofs designed to mimic brownfields compared to green roofs planted with mostly *Sedum* (Kadas 2006). Similarly, vegetation cover (Schindler et al. 2011) and complexity (Madre et al. 2013) are both positively correlated with arthropod species diversity and abundance on green roofs. While rigorous analyses and conclusions regarding the functional or genetic diversity of invertebrate communities are yet unknown, a taxonomic overview now provides information about the types of organisms that use green roofs.

Over the past decade, several investigations of green roofs throughout Europe and North America have confirmed the presence of hundreds of species of beetles (Mecke & Grimm 1997; Jones 2002; MacIvor & Lundholm 2010; Coffman & Waite 2011; Schindler et al. 2011; Braaker et al. 2013; Madre et al. 2013; Meierhofer 2013) and spiders (Brenneisen & Hänggi 2006; Kadas 2006; Madre et al. 2013; Braaker et al. 2013), including species that are rare, endangered or previously unknown to the region (Jones 2002; Kaupp et al. 2004; Gedge & Kadas 2005; Brenneisen & Hänggi 2006). Few studies have also investigated the properties of the roofs or the vegetation that influence the arthropod community diversity but those that have, reveal that site characteristics are important in shaping beetle and spider communities (Braaker et al. 2013). For example, Kaupp et al. (2004) found that beetle species richness was correlated with the successional stage of the vegetation community on green

Lot of test had to be done before living wall installations will become successful. Source: M. Köhler.

roofs, whereby both beetle species richness and activity level was highest on old, grass-dominated roofs compared to young, sparsely vegetated roofs or older roofs colonized primarily by *Sedum* species. Furthermore, this study revealed that vegetation cover alone does not predict beetle species richness on green roofs and that having a mosaic of both vegetated and non-vegetated areas supports a larger variety of fauna, including more rare and endangered species.

Not surprisingly, many species of pollinating wasps and bees, including rare and endangered species (Brenneisen 2005) also make use of green roofs (Mann 1998; Colla et al. 2009; MacIvor & Lundholm 2010; Coffman & Waite 2011; Schindler et al. 2011; Tonietto et al. 2011; Ksiazek et al. 2012; Braaker et al. 2013; Madre et al. 2013; MacIvor 2013; Ksiazek et al. 2014). Although more research is needed to determine which of these very mobile species use these habitats for nesting as well as foraging, it appears that physical properties of the roof as well as availability of floral resources (pollen and nectar) influence the number of visiting and nesting pollinators. For example, MacIvor (2013) found that green roofs on lower buildings and those surrounded by more green space were colonized by a greater diversity of solitary nesting bees. Additionally, Madre et al (2013) reported that bee richness was correlated with functional diversity of vegetation and Brenneisen (2005) found that roofs planted with mostly *Sedum* species attracted only half as many wild bee species as herbaceous roofs. Further investigations are needed to elucidate pollinator response to various components of green roofs, as recent studies in North America suggest that green roofs support a high proportion of non-native bee species rather than local specialists that some plants require for successful pollination (Colla et al. 2009; MacIvor 2013; Ksiazek et al. 2014). Increasing knowledge about pollinator activity on green roofs is especially important as pollination can increase genetic connectivity of habitats and improve the stability and resilience plant communities not only on green roofs (Ksiazek et al. 2012) but also in the overall urban environment (Colla et al. 2009).

In addition to macrofauna, the microinvertebrates and microorganisms living in green roof growing media are critical to the ecological functioning of the roof, aiding in nutrient cycling, organic matter decomposition and food web structure (Rumble & Gange 2013). The non-living components of green roof growing media change over time (Schrader & Böning 2006; Köhler & Poll 2010) and the taxonomic diversity of the critically important microarthropod and fungal communities have recently begun to be investigated. Studies in North America provide evidence that microarthropods, such as springtails (Collembolla) colonize green roof growing media (MacIvor & Lundholm 2010; Schindler et al. 2011). Over time, the community composition of collembolans and other pioneer species becomes increasingly variable (Schrader & Böning 2006). The structure of the plant community as well as environmental factors such as moisture and temperature can affect the species diversity and abundance of microarthropods. For example, species abundance and diversity is low on green roofs containing primarily *Sedum* and mosses (Rumble & Gange 2013). A recent comprehensive investigation has also documented the presence of a robust fungal community on green roofs (McGuire et al. 2013). It is yet unknown exactly how green roof fungal assemblages, unique from other urban habitats, influence floral and faunal diversity. Clearly, much more research is needed to understand how the biodiversity of the overlooked soil-dwelling organisms impacts green roof ecosystems and contributes to urban biodiversity at broader spatial scales.

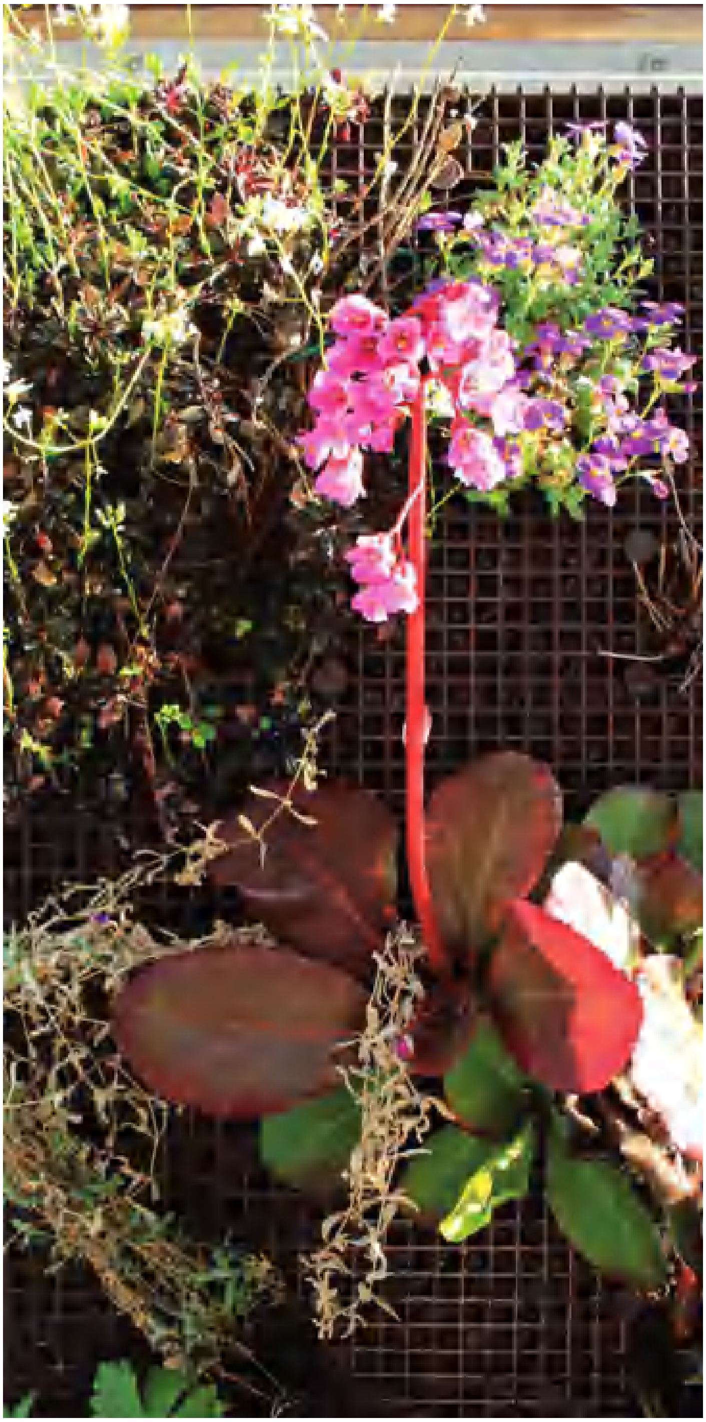
As green roof communities continue to experience successional changes, they have the potential to develop complex ecological interactions and make increasing contributions to urban biodiversity. Though few investigations have been carried out over long time periods, both floral (Köhler 2006) and faunal (Jones 2002) diversity increase over time and green roofs with high plant species and functional diversity gain invertebrate species as the system develops (Kadas 2006). Future investigations carried out over multiple field seasons are needed to elucidate the factors that impact long-term development, persistence, and growth of complex communities on green roofs. Increasing monitoring and management of all urban habitats, including green roofs, will help ensure that the unique biodiversity of cities is supported and conserved.

2.6. Examples

Because green roofs are entirely engineered habitats, considerations should be taken at each step of the design process in order to ensure that the variety of functions provided by green roofs is maximized (Gedge & Kadas 2005). More green roofs around the world are now built with broad ecological goals such as biodiversity conservation in mind. Below, a few examples are highlighted to illustrate different methods being used to help green roofs support high levels of urban biodiversity in temperate climates (Table 1). While there is certainly no one method that is appropriate for use on all green roofs, there are many ways that ecosystem, species and genetic diversity can be enhanced.

Also in the temperate climate zones, lots of variation on plant species are possible in living walls. Source: M. Köhler.

A living wall geofelt test installation to monitor the parameter. Source: M. Köhler.



These few examples demonstrate that a larger variety of techniques can be used to encourage biodiversity on shallow-media green roofs. These methods are summarized in Table 2. In general, varying the non-living components of a green roof to increase habitat variety will help promote greater ecosystem diversity which can provide habitat for a larger number of species. Planting or inoculating roofs with genetically diverse floral, fungal and microbial communities and/or allowing for natural colonization and ecological succession can expand the range of species and genetic diversity. There is also great potential for biodiversity enhancement in other regions including tropical climates as green roof technology continues to become more widespread (Ishimatsu & Ito 2013). While the methods summarized in in Table 2 represent a variety of practical suggestions that could be implemented on most green roofs, many fundamental questions about the practicalities of incorporating green roofs into conservation goals still remain unanswered.

2.7. Recommendations

In these early days of investigating green roof ecology, empirical research determining the potential of various techniques to support all components of biodiversity is still needed. Management intensity, initial construction, and plant selection will influence floral and faunal occurrence and community performance on green roofs as it does in all urban habitats (Müller et al. 2013). As green roof technology and techniques continue to develop around the world, other strategies for biodiversity conservation may become apparent. For example, the use of green facades to connect green roofs with ground-level habitats could assist in migration and colonization of many species which have limited mobility (Braaker et al. 2013). Designing green roofs with intentional ground-roof connections may therefore prove to be a beneficial and commonly used biodiversity strategy in the future. Opportunities for green roofs to enhance biodiversity should not be squandered, particularly due to lack of knowledge, communication, or collaboration. Improvement in three fundamental areas could help realize the potential of green roofs to increasingly support urban biodiversity.

TABLE 1. EXAMPLES OF GREEN ROOFS FROM THE UNITED STATES AND EUROPE THAT HAVE USED TECHNIQUES THAT PROMOTE BIODIVERSITY

CITY	SITE	YEAR BUILT	APPROX. SIZE (M^2)	LOCATION	IMPLEMENTATION
Berlin, Germany	Nature Center Ökowerk	circa 1920	600	A small one-story building located within a nature center surrounded by a forest preserve and a variety of educational gardens containing both non-native and local native plants	The roof of this old water-purification facility was originally covered with a thin layer of sand to insulate the building. No plants were installed and the roof was allowed to colonize naturally for approximately 100 years. In 2006, the roof needed repairs and the entire biotic layer, from substrate to plant layer was carefully removed and returned with additional fresh sand added. Recent vegetation surveys demonstrate that the majority of plant species survived reconstruction. Over 100 species are now present, including rare lichens. (See chapter by M. Köhler, this edition)
	UfaFabrik International Culture Center	1986	350	Several one and two-story buildings clustered in an urban neighborhood surrounded by many street trees, other green roofs and private gardens	Three green roofs were installed as an artistic displayin the 1980s before engineered growing media was popular. Other roofs at this complex were added over the years, as recently as 2012. A mixture of succulent and non-succulent species were planted, including seeds collected from the European Alps. The growing media consisted of mostly garden soil with 10% expanded clay (Köhler 2006). The roofs are not irrigated and maintenance is minimal, usually including removal of weeds and dried plant material once a year. (Figure 2, C)
Munich, Germany	Paper Technology Foundation	circa 1990s	800	Located on a 2nd story walkout of a factory and office building within a somewhat industrialized region, surrounded by paved parking and small private gardens with other green roofs nearby	This roof was an experimental concept, created as a garden to add a diversity of species to the site. Non-living materials were used to create a shallow water-retention area running the length of the roof. A wide variety of plant forms were included in the original design including several native forbs and woody shrub species. Maintenance is minimal and natural colonization is generally allowed. There are currently over 100 plant species found here, including a variety of aquatic species. (Figure 2, D)
Basel, Switzer-land	University Hospital Basel, Klinikum 2	2003	3000	In the heart of the city, near a large river, surrounded by many other buildings with green roofs and several private gardens which include native plantings	A variety of substrates were installed, including sand, gravel, shingle, and topsoil (Brenneisen 2005). Substrate coverage varied not only in composition but also in arrangement and depth. A variety of plant species were planted and others were brought in as seed with the meadow topsoil that was mixed in with the other components of growing media.

CITY	SITE	YEAR BUILT	APPROX. SIZE (M^2)	LOCATION	IMPLEMENTATION
Chicago, IL, USA	City Hall	2001	2500	Thirteen-story building spans a city block in a heavily urbanized neighborhood, near a large city park and in close proximity to a large lake	The roof is mostly extensive with two intensive areas to accommodate small shrubs. It is a showpiece of green roofs for the city, often used for tours, and was planted with a combination of over 200 native and non-native forb, grass, and succulent species. The roof is irrigated when needed, new species are added frequently and the roof is intensively maintained during the growing season to manage slightly aggressive grasses and weedy species (Dvorak & Carroll 2008).
	Chicago Botanic Garden Rice Center for Plant Conservation	2009	1600	A two-story laboratory, located within a large suburban botanic garden which includes thousands of native and horticultural species, near a large golf course and many private suburban gardens	This roof is mostly extensive with variation in media depth and inclusion of several media trays. It is divided into two main sections, one devoted mostly to local native species and the other to succulents and more traditionally-used varieties, totaling over 150 species. The roof is not irrigated but regular maintenance includes removal of weedy species. All species are monitored throughout each year as part of a large plant evaluation program. (Figure 2, B)
Fort Worth, TX, USA	Botanical Research Institute of Texas	2010	2600	A two story building, part of research facilities outside of the city center, between an industrial area and forested natural habitat	The roof was constructed from biodegradable coconut fiber trays. Engineered growing media was mixed with calcareous topsoil that was harvested from a local prairie. Originally 40 species were planted including several species native to limestone barrens of Texas (Dvorak et al. 2012, B.Byerley, 2014, pers.com.). Additional species have colonized from seeds in the growing media. Arthropods and nesting birds have been observed on the roof.
London, England, UK	Trinity Laban Conservatoire of Music and Dance	2002	360	Located in the Deptford neighborhood, in a heavily urbanized area near a large river, surrounded by lawn but limited other vegetation	Initially designed as a “brown roof” to provide nesting habitat for the rare bird *Phoenicurus ochruros* (black redstart) using local crushed concrete and brick as growing media. The roof was allowed to colonize naturally and has been supplemented over the years with a commercial seed mix as well as seeds collected from regional meadows (Burgess 2004; Grant 2006). Additional structures including dead wood were added to provide habitat diversity. (Figure 2, A)

Increased communication and collaboration among stakeholders

With the dramatic rise of urbanization over the next two decades, communication must be enhanced between industry practitioners, scientists, politicians and urban planners. Green roofs can meet the needs of many organisms when expertise in design,

FIGURE 2. BIODIVERSITY GOALS WERE CONSIDERED DURING THE DESIGN OF THESE EXTENSIVE GREEN ROOFS.

A: Several plants, lichen, insects and fungi use a decaying log on the Laban Dance Centre, London, United Kingdom. B: Over half of the green roof is devoted to evaluation of native prarie species at the Chicago Botanic Garden, Glencoe, IL, USA. C: Two coccinellid beetles use a green roof for mating habitat at the UfaFabrik Cultural Center, Berlin, Germany. D: Small ponds and a variety of algae, shrubs, grasses and forbs provide unique habitat on the green roof at the Paper Technology Foundation, Munich, Germany.

TABLE 2. MANY DESIGN AND/OR MAINTENANCE TECHNIQUES USED ON GREEN ROOFS CURRENTLY SUPPORT URBAN BIODIVERSITY GOALS

METHOD	BIODIVERSITY ASPECT SUPPORTED
Vary substrate composition	Ecosystem, Species
Vary substrate depth	Ecosystem, Species
Create micro-habitats	Ecosystem, Species
Irrigate when needed	Ecosystem, Species
Remove aggressive species	Species
Plant/inoculate with a variety of species	Species, Genetic
Use organic materials from the natural environment	Species, Genetic
Allow for colonization and succession	Species, Genetic

construction, ecological processes, writing policies and implementing guidelines are brought together. National and international conferences exists in which members of various fields come together to discuss new methods, products and discoveries. However, annual meetings can be cost prohibitive and do not always have the capacity or time to facilitate necessary discussions. So, how can stakeholders from all fields bring their relevant knowledge to the table? Scientists can make suggestions based on ecological theory gathered from other systems and, more importantly, test these theories within the urban and engineered framework of green roofs. Where possible, scientists should write transparent and easily accessible reports of their scientific findings specifically to inform the green roof industry. Architects and engineers can determine the practical limitations of green roof technology and implement realistic solutions that combine the best ecological and technical practices. Politicians and urban planners can assure that when environmental regulations are written, especially in urban areas, they contain specific guidelines for helping conserve and promote biodiversity on all green roofs. Together the knowledge of the community can be used to achieve high yet realistic goals.

Understanding the full breadth of ecological interactions on green roofs

Research regarding ecological processes on green roofs is still new or nonexistent in most regions. The full scope of community interactions that take place between fungi, plants, animals, and microorganisms on green roofs is yet unknown. In this engineered habitat, what factors limit achievement of goals that would support all aspects of biodiversity? Green roofs will never replace natural habitat, so what are reasonable expectations for ecological processes in these systems? Are there a set of common biodiversity targets that can be applied to green roofs globally? A great opportunity exists for scientists to use what is already known about biodiversity conservation from other habitats to begin to answer these questions. Ecologists should expand the scope of their research beyond green roof taxonomic diversity and should look for ways to collaborate at regional, national and international levels. As more is known about the community and ecosystem-level processes which occur on green roofs, these innovative habitats will have even greater potential to support all facets of biodiversity.

Connecting green roofs to the larger urban environment

Beyond the potential of green roofs to provide habitat and resources to a small number of organisms that live within their confines, these small habitat patches may have the ability to make larger contributions within urban environments. Little research has been conducted in this area but will likely be necessary in the future to determine how green roofs interact with other urban green spaces and other green infrastructure to form larger metapopulations. Are green roof plants a seed source for nearby natural areas? How should green roofs be designed and managed to ensure that they do not become havens for pests or invasive species? Do green roofs act as stepping stones for mobile species and contribute to urban corridors? A recent investigation has now demonstrated that connectivity in the landscape shapes arthropod communities on green roofs (Braaker et al. 2013). Further ecology research incorporating a network approach is necessary to understand the ways that organisms on green roofs are functioning within the larger urban community (Elle et al. 2012). Urban planners could strive to incorporate green roofs with high ecosystem, taxonomic and genetic diversity into city-wide conservation strategies, particularly by including these habitats as part of linear landscape elements and linear greenway sites (Jim & Chen 2003; Jim 2004; Van Rossum & Triest 2012). This strategy would support local and regional biodiversity by providing resources to transitory species such as migratory birds or highly mobile pollinating insects that move through the landscape.

3. CONCLUSIONS

As the number of green roofs continues to rise globally, so does the potential of this technology to contribute to both local and global biodiversity support. Conservation efforts that enhance biodiversity on individual green roofs can contribute to larger collective and systematic efforts to create connected habitats and encourage overall genetic, species and ecosystem diversity in cities (Savard et al. 2000; Millennium Ecosystem Assessment 2005; Van Heezik et al. 2012). As with biodiversity conservation in all habitats, urban planners and policy makers will need to set both specific short-term targets as well as long-term goals in order to ensure that biodiversity is sustained in the future (Millennium Ecosystem Assessment 2005). Solutions which focus on a single aspect of green roof habitat such as abiotic components (Quigley 2011) or species diversity, will likely not be enough to adequately create resilient, robust communities and thwart the loss of biodiversity (Cook-Patton & Bauerle 2012).

Research addressing the use of green roofs to conserve complex biodiversity will need to be multi-faceted. As stated in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005), no single component – ecosystems, species or genes – is consistently a sufficient indicator of overall biodiversity because these components can vary independent from one another and across space and time. The needs of every city are unique but biodiversity conservation can be achieved on green roofs when their design and management is incorporated into multi-scale and multi-stakeholder planning (Henry & Frascaris-Lacoste 2012). Research regarding biodiversity on green roofs thus far has made great strides in a short period of time and has contributed to the current understanding of the complexity of green roof ecology. Additional studies will allow scientists and practitioners alike to explore the full potential of green roofs and their contributions to the conservation of biodiversity at all levels.

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CHAPTER 7

GREEN ROOFS IN SCANDINAVIA:
AN URBAN PLANNING ANALYSIS

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ABSTRACT

Scandinavia has a long and famous tradition of green roofs, especially turf roofs. Today the design of green roofs follows new modern designs that meet many purposes. A "green space factor" was used in the development of the new sea-side housing area Bo01 in Malmö in Sweden and a green roof was among the approaches used to meet this requirement. Some years later after Bo01 in Malmø, Copenhagen started integrating green roofs into urban planning. For the last three years, Norway has intensified their focus on green roofs, creating reports and hosting workshops as preparation for integrating green roofs into planning. The process in Helsinki is mainly at the research level. Green roof planning, policy tools, regulations and projects are being used for inspiration among cities in Scandinavia though networks, green roof associations, workshops and conferences.

KEY WORDS

Sustainable, Climate Adaptation, Urban Planning, Green Surface Factor, Malmø, Stockholm, Copenhagen, Oslo, Helsinki.

1. INTRODUCTION

Green roofs have a long tradition dating back to the Viking and Middle ages in Scandinavia. Turf roofs were commonly applied to Scandinavian cottages, especially in the northern parts of Sweden and Norway over 1500 years ago. Turf was the main material as it was locally abundant and available. It helped create effective insulation and has more or less been used continuously in Scandinavia. It is still used and to some extent a few examples still exist.

Today, cities worldwide as well in Scandinavia are looking at tools that can meet the needs of improved storm-water management, regulation of building temperatures, reduced urban heat-island effects, creating aesthetic and health benefits and increased urban wildlife. Green roofs have been shown to be a growing part of the solution of being part of the ecosystem services that can meet the need of today without compromising the needs of future generations.

During the 1990s, green roofs became a part of the wave of ecological buildings and the eco-villa concept that was developed in many parts of the

Scandinavian countries during this decade. Urban development with green roofs as part of the planning started in the beginning of 21st century within the context of creating liveable, sustainable and climate-adapted cities.

2. SWEDEN

In Sweden the appearance of the modern green roof has been growing since the beginning of 2000. A starting point was the Bo01 in Västra Hamnen, a new developing district with the main aim to create an international showcase of environmental adaptation and social sustainability in a high-density urban area. The purpose was to benefit the sustainable development of Västra Hamnen and Malmøs. At the same time, Augustenborg's Botanical Roof Garden was created with a main aim of supporting sustainable development though increased usage of green roofs in Scandinavia.

The Miljöbyggprogram South[1] was developed in collaboration between Lund Municipality and Lund University. Miljöbyggprogram South contains various aspects of sustainable construction, including urban biodiversity that includes a green surface factor, or GAF. The green surface factor is a valuation of the site's green area. The model is designed to put a quantitative value on how a higher proportion of greens to be achieved in connection with the development of municipal areas. The model sets the value of different types of vegetation including on the basis of the amount of water that may be infiltrated and absorbed.

The client must present a calculation of how the planned management of the site should be utilized before planning permission is given. Different surfaces are given different values. There are different ways for a client to achieve the requirement of green surface factor and oftentimes this includes a green roof. However, there are no special requirements for green roofs. The requirements imposed on the green surface factor complied with in relation to the requirement set.

Green space factors are also used in Norra Djurgårdsstaden, Stockholm. In this project, extensive green roofs (50-300mm) are given a factor of 0.1 and semi-intensive green roofs a factor of 0.4. Green roofs are, however, also given an extra factor of 0.1 due to their positive effects in relation to avoiding urban heat island effects[2].

Several Swedish municipalities give permission for larger explorations of ground area or an extra floor if buildings are covered with green roofs. Several Swedish municipal housing companies have also written policies to invest in green roofs as a preferred alternative in new housing areas and in refurbishment projects (an example is the municipal housing company, Mimer, in Västerås).

The city of Stockholm has made a decision to invest 205 million SEK in a large energy-saving project between 2010 and 2013. Green roof installation is one of the strategies that will be applied in this project, but not one of the major strategies (Stockholm municipality, 2012)[2].

Based on the initiative in Malmö, the use of open storm water management efforts, green roofs in particular, has been an inspiration in Scandinavia.

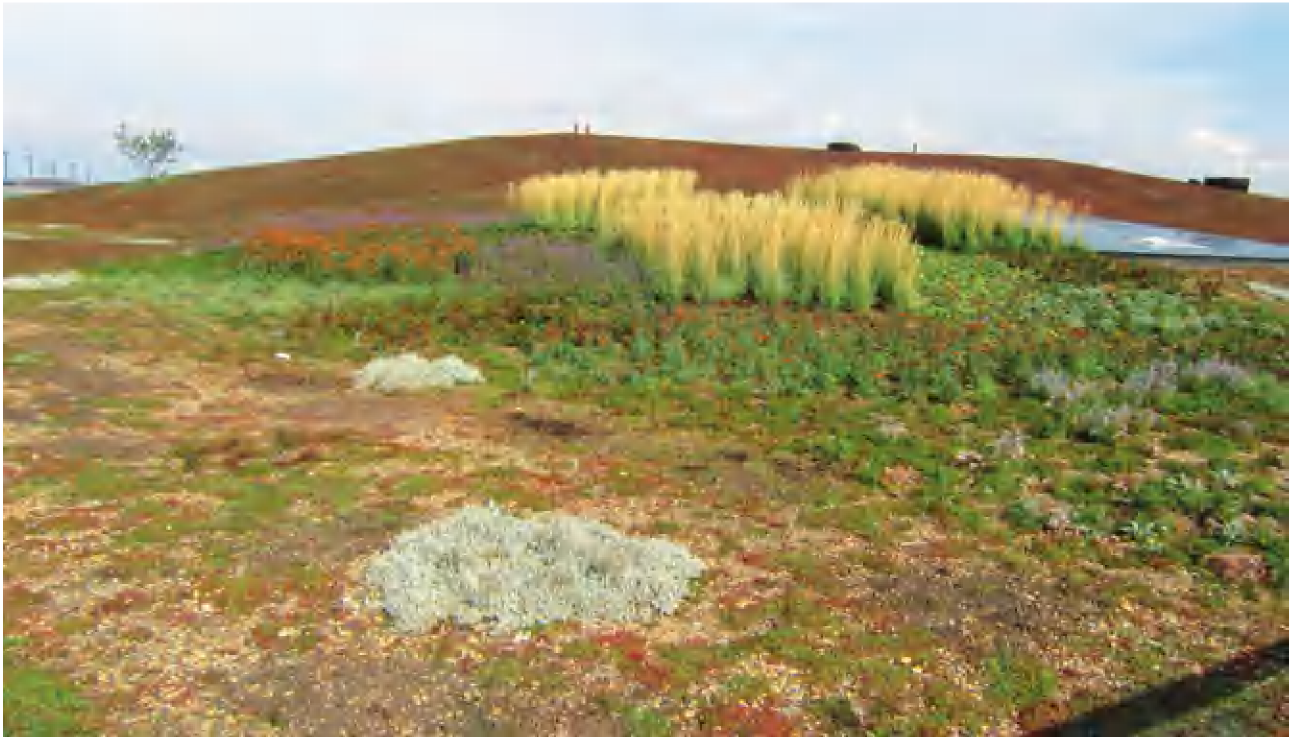
A green roof project in Sweden:

Sten & Ström Emporia Shopping Center

On top of the Emporia Shopping Center there is a publicly-accessible 27,000 square meter green roof park. The idea is that the park will serve as an oasis, providing the opportunity to sit and relax on top of Emporia.

The architect Gert Wingårdh has designed a lush landscape where ventilation equipment and other technology are hidden in artificial hills, creating an undulating roof park with over 50 different species.

The green roof will be part of an aesthetic experience while evaporating the rain and



Sweeden Green Roof on shoping center. Source: Dorthe Rømø.

reducing the load on the stormwater system at the same time. Overall, the assessment is that the roof will contribute to a better environment in Hyllie.

In autumn 2011, the first part of roof park was finished. The roof area was designed with seven hills and to promote biodiversity, therefore it was built with different types of green spaces and planted with *Sedum*, perennials, grasses and trees. The roof consists of a total of over 30 000 plants. There is a lawn for play and rest. Next to it is low-growing vegetation with plants like cat feet, bluebells, crocuses and wild tulips creating a blanket of different *Sedum* species. A beautiful planting with tall ornamental grasses and flowering perennials was created on the park and will bloom in the spring. On the hill, the more modest, evergreen plant mix, which is commonly found on green roofs, was chosen. The plant mix consists of extremely drought -resistant plants, such as Sedums and various herbs and mosses, which will provide a lively take on changing nature year round. Emporia is the first shopping center in Sweden that is certified under BREEAM, a leading method for environmental certification of sustainable construction.

3. DENMARK

In Copenhagen, attention to green roofs started in 2008 when the city approved its waste water plan[3]. In this plan the framework for working with sustainable urban drainage was described. As part of the process of integrating green roofs into the city's planning, a wide range of workshops, seminars, and conferences were held, where the subject of green roofs was the theme or one of several in relation to the overall theme. It has created awareness to bring green roofs into the planning processes of the city of Copenhagen as well as rest of Denmark.

Since then, green roofs in Copenhagen have evolved and knowledge about the potential of green roofs has increased.

Based on research and international experiences of green roofs proving a multitude of ecosystem services, green roofs became a part of Copenhagen's climate plan in 2009[4]. Since then, they have also become a part of the city's Strategy for Biodiversity[5], Guideline for Sustainable Urban Drainage[6] and Climate Change Adaptation Plan[7]. The Green Roof Policy back in 2010 mandated that green roofs became a part of the municipal plan of 2011[8], and became a framework for setting requirements for green roofs in new local plans. In the same year, a guideline for the environmental construction of buildings owned by the municipality with a focus on green areas and sustainable drainage on urban green roofs became mandatory for the municipality's own constructions[9].

Since 2010, green roofs have been mandated in most new local plans, providing approximately 200,000 square meters of green roofs in the coming years. This is based on approved local plans from 2010 and 2011, so even more are expected over the years.

The interaction between many parties is an important part of the project. It helps to create a dynamic process, further clarify needs in relation to the project and, at the same time, is itself a part of an iterative process. Today, most urban planners, consulting firms and architects are familiar with the concept of green roofs to some degree.

The planning and policy development in Copenhagen seems to be inspiring green roofs movement in Scandinavia. An exchange of experiences and inspirations has been shared though workshops and conferences.

A green roof project in Copenhagen: The New Danish National Achieve

The green botanical corridor is a project that is interesting in many aspects. It's a development of a green high line in one of the most traffic-heavy streets of Copenhagen near the inner harbour. That's one of the areas in Copenhagen with the least amount of green area per capita.

Green on the parking SEB. The City Dune. Source: Dorthe Rømø.

Green roof park New National Achieve. Source: Dorthe Rømø.

The city chose to establish a new, green highline elevated seven meters, which, when it's finished, will connect two urban areas. When finished, it will be composed of at least four connected green roofs on four separated buildings. This green botanical corridor will be accessible to the public for walking and cycling from one area of the city to another in green surroundings away from heavy traffic.

Today you can go straight up to the first green roof from the street. A sculptural staircase rises seven meters and is covered with trees inspired by the Scandinavian landscape. It's the first green roof covering a parking lot between SEB bank's two buildings. The green roof is called The City Dune and is quite popular for skaters so to an extent, a new liveable area has been successfully created.

From this roof, you move forward over the green roof garden on the new National Achieve. The garden has been planned with a primary path creating an axis running across the total length of the project. Along the axis, several spaces are defined to be elevated strawberry beds with integrated benches and espaliers that will, over time, become overgrown with intertwining, flowering plants, thereby creating well-defined spaces. These spaces have been created for the public to sit and have lunch, read a book or relax and listen to the busy bees and enjoy the scents from the thyme.

The green roof garden on the new National Achieves merges into the green roof of Tivoli Congress Centre with beautiful trees and shrubs and colourful tulip beds in the spring. In this way, a fine green view has been created for the guests at the Tivoli Congress Centre, Tivoli Hotel and the Wakeup hotel as well. The uppermost level of both hotel buildings also has a thin green roof solution consisting of *Sedum* plants.

The project is in many ways unique in its form and its expression with green roofs on various buildings that are connected to each other,

Green roof gardens on Tivoli Congress Center. Source: Dorthe Rømø.

available for the public and connect two urban areas.

The green roof has a park-like function with the opportunity for skaters to express themselves and with the possibility of anyone walking or cycling from one end of town to the other in peace and quiet and away from traffic.

The urban development in Kalvebod Brygge can serve as a showcase for future urban sustainable design and development. It shows how we can maximize the use of many thousands of square meters of unused potential, and create multi-functionality of buildings for the benefit of the city and society as a whole.

4. NORWAY

Cities of the Future is a collaboration between the government and the 13 largest cities in Norway to reduce greenhouse gas emissions and make the cities better places to live. The Cities of the Future programme will help city municipalities to share their climate friendly city development ideas with each other and with the business sector, the regions and the government.

This programme runs from 2008–2014. The 13 cities are: Oslo, Bærum, Drammen, Sarpsborg, Fredrikstad, Porsgrunn, Skien, Kristiansand, Sandnes, Stavanger, Bergen, Trondheim and Tromsø.

The City Council of Oslo has adopted the "Urban Ecology Programme for 2011-2026"[10]. This program has the following vision: "Oslo will be a sustainable urban community where everyone has a right to clean air, clean water and access to quality recreation areas." To realize its vision of environmentally-friendly and sustainable urban development and operation, the municipality has set up a list of eight priority areas. The area "reduce noise, air pollution and greenhouse gas emissions," specifically noted green roofs as a measure, along with establishing more green space, as specified in the "Oslo to adapt to climate change." Priority 5 pointed out: "Oslo will preserve and enhance its blue-green structure." There are also naturally green roofs as part of the chain of possible measures, although it is not specifically mentioned here.

Examples include the Barcode-House in Oslo where it is requested that 50% of the buildings have green roofs. For Barcode, the following provision is used (extracted from zoning regulations):

"4.5 Roof terraces
b Vegetation: Theremust be at least 50% green roofs on all buildings, in the form of Sedum mats and/or grass and with bushes and trees for temporary absorption of rain".

By integrating these requirements into municipal planning, it will be difficult to avoid these decisions by dispensation because the municipal regulation is part of a more holistic plan for use of an area within the municipality.

In Bærum municipality they have established guidelines for the use of open water solutions in the district Fornebu. This has been and is being done by recommendations from an R & D project "Open water solutions, experiences and recommendations" (Public Construction 2004). Green roofs have not been themed specifically, but will be applicable here as one of several steps in the chain of methods used to deal with the water.

With inspiration from Sweden the green factor (GAF) has been used for urban development regulations in the area of Filipstad, which has opened the use of green roofs as an approach to meet the target.

In 2010, NOU #10[11], "Adapting to a changing climate. Society 's vulnerability and the need for adaptation to the consequences of climate change," mentions five points that are important to have in place to successfully incorporate climate change adaptation work in general into the municipalities. These are: "1. A solid and accessible knowledge base. 2. Competence and capacity to adaptation efforts. 3. National support and their clear lines of management. 4. Priorities and resources. 5. Cooperation across sectors and administrative levels." In relation to the desire of implementation of green roofs in municipal planning, it provides this knowledge about project acquisition and makes an important contribution to paragraph 1 of the NOU report.

The third paragraph in NOUs is on its way through the Ministry of Cities of the Future project, where the participating municipalities have chosen that the theme will focus on the field of climate change. Within this context, Bærum and Oslo City Council have decided to obtain more knowledge about green roofs to recommend this as a priority. Cities of the future will again be pioneering examples for others who want to promote green roofs[12].

Norway. Photo credit Joachim Seehuse.

A green roof project in Norway: Veolia recycling center in Haraldrud, Oslo, with 28,000 m^2. 2008

The establishment the green roof on the Veolia recycling center is Northern Europe's largest *Sedum* roof (28,000 m^2) that contributes to creating a favourable local climate, reducing the need for stormwater management. Furthermore, the roof surface that is clearly visible from the hills along Groruddalen is a positive element that changes colour and character with the seasons. It has contributed a large volume of nature and despite its size, it's seen as a positive contribution to the community in general. The plant will eventually be surrounded by vegetation strips of vines in bright colours and rows of poplars.

The project was selected to participate in the Word Architecture Festival in 2008 and was awarded the Scandinavian Green Roof Award in the same year[13].

5. FINLAND

Finland has started green roof development from the perspective of research. Finland is running a research program called Fifth Dimension – Green Roofs in Urban Areas that is carried out by the Urban Ecology Research Group at the University of Helsinki and is funded by the Regional Council of Uusimaa.

Helsinki hosted a scientific meeting in 2012 with the aim of discussing the possibilities of transdisciplinary research on green roofs and to introduce the current international green roof research to the Finnish audience, with a focus on biodiversity and ecosystem service promotion on urban green roofs. They are looking at how to combine the studies and theories of different disciplines and multifaceted perspectives to produce fruitful outcomes. The goal was to to find the best solutions and practices for sustainable green roofs[14].

A green roof project in Helsinki: BIBLIO-Centrum", HELSINKI CENTRAL LIBRARY, The Heart Of Metropolis Helsinki, Finland http://www.dinkoffarchitects.com/frames/cultural.htm

Green roof in gift shop. Source: I. de Felipe.

6. CONCLUSIONS

The work that lies ahead of Scandinavia is to make guidelines that can work as an inspiration for both urban planners as consultants and building owners. Guidelines will help clarify the choices to be made from the very beginning of each project. Valuation of green roofs is needed as well. Valuation of green roofs as an ecosystem services tool in urban planning, will help cities in Scandinavia figure out which regulations, combined with financial incentive structures, will trigger the main purpose from a city viewpoint. Priorities and tools will vary depending on region, culture and local ecosystems service needs. A strong tool in this process is the cooperation across countries and sectors like science institutions, public authorities, politicians and the private market. These interactions can help qualify the way and form that green roof development can take. They can be enhanced by inspiration from pioneer projects, planning and policy, and can serve as a platform from which we can accelerate the transition of cities to more sustainable and climate-adapted ways that re fitted to the needs of countries' and cities' contexts and cultures.

Steps have been taken in the cities of Scandinavia to move ahead with a green transformation by means of green roofs. Urban areas have been developed using green factor tools, green roof policy and planning has been integrated into green roofs, research reports have been created, and excellent green roof projects have been designed and created.

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CHAPTER 8

URBAN AGRICULTURE IN THE GREEN CITIES FRAMEWORK: EVOLUTION AND CHALLENGES

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ABSTRACT

Urban agriculture (UA) has been a traditional activity which in recent decades has developed very fast in new megalopolises. A new green cities movement based in advanced technologies allows farming where agriculture has a new horizon. The challenge is how to get social welfare where the economy is combined with food supply, landscape and health in a sustainable way.

The role of agriculture in urban sustainability has multifunctional dimensions (food, energy saving, water management, biodiversity and others) where innovation (aquaponics, greenhouses in terraces) may improve its performance. Urban policies have the challenge of looking for synergies in the factors involved in urban agriculture, with adequate planning for green areas and socioeconomic development. Among the activities to consider are the promotion of local food products, contractual regulations, urban markets, customized agrochemicals and other inputs.

UA creates a socioeconomic framework, employment opportunities, food supply, improvement of environmental conditions, recreation and leisure, embedded in the urban green revolution.

KEY WORDS

Green cities, urban agriculture, innovation, local policies, environment, evolution

1. INTRODUCTION

The way of functioning of many of our cities is quite different from its original planning, which has been inherited by the actual citizens. The environment is changing very fast. New infrastructure and constructed buildings and other facilities tolerate great crowds.

A fully covered wall with a felt system in Tokyo. Source: M. Köhler.

The quickly growing movement of urban areas, in developed and developing countries, raises great concern about their sustainability (Deelstra and Nijwening, 1997).

The international summits (Istanbul, 2004, Rio de Janeiro 2012, and others) discussed sustainable development principles, their evolution and their components. These deal with technology, economic, social and demographic studies, and analyze with new parameters the natural resources used and the waste produced.

One of the problems of UA is that in many cases it is established in an informal way, outside of urban regulations. That may be complicated by having data and reports of the benefits and positive effects. Their illegality creates problems with local authorities and barriers to new regulations, municipal policies and development subsidies.

The paradox is that areas which formerly were of agrarian activities, after being transformed into building complexes under speculative movements, are very difficult to recuperate for green land. However, the economic crisis and the degeneration of living conditions in urban areas, with high levels of pollution and heat islands, are forcing the political institutions to look for new solutions, where green and food farming are basic instruments.

The challenge is whether our biosphere may accommodate all the requirement needed by cities. Urbanites have to change their consumption habits, plan new urban rules, regulate themselves and look forward to sustainable systems. There are several frontiers to work for new urban areas, with the goal to increase human welfare. We have to improve efficiency in energy, water management and microclimate, food supply, recreation and landscape, biodiversity, atmospheric and acoustic pollution. Here is where urban agriculture may perform positive actions for all of them. In this chapter we describe some of the most significant dimension of new agriculture, its role in the sustainability, innovation, local policies and future perspectives.

2. GREENING CITIES EVOLUTION

At the beginning, human settlements were located in zones with attractive economic and commercial development. The deltas and river valleys allowed for productive agriculture and the crossroads of communication routes and harbors facilitated economic activities.

At that small scale, villages were surrounded by nature and orchards were annexed to the family house in a formal way, supplying basic and fresh food.

The rapid growth of the urbanization process eliminated the green zones from urban environment. As a result, houses stayed close to each other but were surrounded by walls, like in a fortress, and isolated from nature. Thus, new citizens appreciated how the gap between urban and rural worlds was increasing and, along with that, their habits and way of life.

Socioeconomic factors stimulated the urbanization process. The migration from rural areas has created new megalopolises, where contact of the new urban dwellers with nature is a luxury only available to a privileged minority.

Urban areas, especially in undeveloped countries, grow in an anarchical way, sometimes with illegal invasions. The new construction leaves very few free spaces between them.

Simultaneously, the already urbanized zones look forward to incorporating nature in their free zones by means of agriculture in height (facades, terraces, balconies). The result is the characterization of the new large city, with a sprinkled map of gray zones (construction) and green (nature), which we could consider an archipelago.

Toronto. Green terrace. Source: I. de Felipe.

The challenge is to obtain social welfare, where economy is compatible with health, landscape and food supply among other things, and all of it in a sustainable form.

The idea of a "green city" (Roelofs, J. 1996) has a controversial and utopic evolution. The

URBAN GREENING EVOLUTION

Garden of Eden is anti-urban, and Plato's Republic establishes the basis of the green city. The city-state was an educational institution with ecological wisdom.

During the Mediaeval and Renaissance periods there were several expressions looking for the ideal city and later on in the 19th century, socialist movements (R. Owen, C. Fournier) were concerned with the environmental consequences that originated from the industrial revolution and new capitalism.

Urban planners should have joined environmentalists looking for the eco-city framework, where the main goals are health, green environment, resource conservation, waste reduction, reduction of toxins and pollution and participatory process with cultural vitality. We are in the take off period for private initiatives.

In Montreal, Lula Farms, located near the Central Market, supply fresh food weekly with an efficient value chain and with quality control, certification and marketing labels (Gunter Pauli, 2012). In fact, the establishment of urban markets where urban and rural farmers may participate together is a good solution for the citizens to get fresh food, increased transparency and diminish environmental impact.

The Ogden International School of Chicago. Source: Greenroofs.com; Photo Courtesy: Carlisle SynTec Systems.

Although economic growth has been considered the highway for a good life, there are serious critics of it, in favor of the 3Rs: Reduce, Re-use and Recycle, activities sponsored by the local administrations. Thus, the evolution of analyzing greening cities is an important source of information and identification of potential measures to propose.

3. THE ROLE OF AGRICULTURE IN URBAN SUSTAINABILITY

Urban agriculture (UA) may include intra and peri-urban regions and ornamental and food production activities, with significant impacts on sustainability.

There are some basic questions we will discuss in relation to UA and sustainability:

3.1 Agricultural areas location

The first point is where to find space for agriculture, and there are different possibilities. The traditional one has been in vacant land and spaces reserved in urban planning. Ornamental agriculture has been frequently used in developed countries (gardens, parks, trees in the streets). However, the up-agriculture in living walls, green terraces, balconies or inside the buildings is becoming important.

In cities with an economic crisis or new structural plans, there are vacant lots and buildings where people may plant gardens and orchards: London, New York, Detroit, Chicago, Toronto, Berlin, Madrid, Copenhagen and other cities have examples of this new urban agriculture. In all cases, one of the main concerns is the negative impact of urban pollution if the orchards are close to busy roads or contaminated places.

3.2 Waste and nutrient recycling

Nutrient recycling and waste management are basic for the sustainability of urban ecology.

However, while in traditional urban areas, the metabolism has been circular using similar products, in modern cities, there are many products from different origins, and inputs and outputs are treated together. Sewage, treated or not, is sent into rivers and coastal waters downstream and its fertility is lost to farmland. At the same time waters are polluted by sewage and the use of agrochemicals from farmland.

The metabolic system of many cities is not sustainable in these conditions. It is necessary to reduce waste through different ways, again, the reminder of "re-use, reduce and recycle".

Here is where urban agriculture has a significant task. Packing of food can be re-usable or biodegradable. Agriculture can use organic wastes. Thus, the cycle of nutrients through urban waste is an example to follow. Some experiences include composting, waste water use, recycling urban nutrients or re-using waste from buildings (central heating) or industries.

3.3 Energy recycling and reducing urban warming

Modern cities consume energy for socioeconomic activities. In some cases, part of the energy is sent to the atmosphere, creating the heat island pollution problems.

In many countries, especially during the cold period of the year, buildings and fabrics deliver gas from central heating and other sources, which may be recycled into UA through greenhouses.

The production of horticulture and ornamental plants may be a profitable business, selling the products in conventional markets. Simultaneously, the plants absorb CO_2 and use the heat to warm their environment, increasing their productivity. Thus, urban warming is reduced and transport of food from outside the city will diminish. As a consequence, the energy and carbon footprint of the urban areas may be balanced in a positive way.

The VanDusen Botanical Garden Visitor Centre. Source: Greenroofs.com; Photo Courtesy: ZinCo. Para : Energy, landscape.

The concept of an urban ecological footprint includes the material and energy consumption and the waste produced, which a finite area of land and water is required to produce or absorb (Wackernagel M. and Rees, W. 1996).

Ecological footprint analysis requires knowledge of natural capital, the supply and potential demands. There are several ways to reach the equilibrium and diminish the instability, reducing the energy and natural resources demanded and decreasing the waste. Sometimes, the potential suppliers are located thousands of kilometers away.

3.4 Water management

Green areas have permeable land which allows the rainwater to runoff and drain. In contrast, standard roofs and streets have hard covered surfaces that increase the volume of flowing rainwater, especially during storms, and increase the risk of floods. For this reason, green surfaces diminish the investment costs for water sewers and drainage systems.

In Germany, for example, there are especial fiscal advantages for green roofs which absorb rainwater.

At the same time, rainwater and wastewater may be recovered and used to irrigate urban agriculture. However, in the case of wastewater the re-use requires special investment to separate and treat the water in an adequate way. Otherwise, there is a risk of environmental contamination.

3.5 Landscape and environmental awareness

Bringing nature into urban areas improves the landscape and surroundings of people. The increase in productivity and decrease in stress are some of the results. At some point, urban agriculture (UA) may change urbanites' perceptions of their food. Many of them, especially children, only "harvest at the supermarket". When crops are locally cultivated people have the chance to observe and practice urban agriculture and understand the food

Urban agriculture. La Havana. Source: I. de Felipe.

chain from the beginning. Thus, it is a re-education process linking food production with the consumer.

In a way, the citizens may better understand the agricultural problems and get closer to rural areas and farmers' activities.

3.6 Biodiversity

Although on a small scale, the urban environment is quite often richer in flora and fauna than the farmland. In cities there is a greater variety of plants, flowers and trees than in the intensive farmland, with little uncultivated areas. Different situation are found on urban green roofs than in forests, parks or uncultivated rural areas. (Gedge D., Kadas G. 2005; Ksiazek et al. 2012)

Urban farmers lack resources and legal administration knowledge to defend biodiversity and other activities. Therefore, experiences may influence how other cities overcome similar barriers. International organizations (WGIN, IGRA) may lead and cooperate to expand knowledge and communication between the citizens.

The Atlanta Botanical Garden. Edible Garden Green Wall and Outdoor Kitchen. Source: Greenroofs.com; Photo Courtesy of Tournesol Siteworks.

4. INNOVATION AND OPPORTUNITY COST IN URBAN AGRICULTURAL ACTIVITIES

Green measures are sometimes costly and their benefits have to be explained. Adequate information may reduce the risk to pioneers. Therefore, public intervention should be involved in the promotion of green areas considering all the social benefits and positive impacts in relation to their costs.

Lifecycle cost analysis (an analytical method that calculates the cost over the useful life of an asset) indicates that low front expenditures, though easier to finance at the begining, may result in higher costs over the total life of the system. Thus, choosing lowest first cost is a poor life-cycle decision, because energy, maintenance, human productivity, water efficiency and other elements have to be factored into the analysis (US Green Building Council. 1996).

The local administration should be aware that adoption of green building practices may reduce public expenditures for water, energy and waste processing. Besides that, as they own and operate their own buildings, local institutions may improve environmental conditions.

Cities should be "greened" considering different scenarios (economic, social, political, and ecological) following key values (Roelofs, J. 1996): ecological wisdom, social justice, grassroots democracy, non-violence, decentralization,

The Flagship Brooklyn Grange Farm in Queens, New York. Photo Courtesy and CroofliteR, Skyland USA.

community bases, economics, feminism, respect for biodiversity, personal and global responsibility and a future focus.

Urban agriculture has been relegated on innovative advances while being focused on rural agriculture for a number of reasons. From an economic point of view, agriculture has always been considered a complementary urban activity related to food supply or leisure. Socially, the niche of urban farmers has been exotic, related to the green or progressive movements, unemployed or retired people. Therefore innovation in UA has had poor institutional support, lack of training and quality control of products, and no incentive for innovation. The small-scale production and low productivity has been the pattern of this activity.

At the same time, there has been harassment of urban development plans, which accuse the UA of a lack of hygiene and bad smells. All of that together with speculative pressures have reduced green areas (not only those of food production) to a symbolic presence.

However, the circumstances are changing. Dwellers who do not have the possibility of living in the suburbs (greener areas) suffer sickness and stress from pollution. Their environment is highly contaminated and lacks the presence of nature. Traffic is increasing and the current situation is not sustainable.

Large cities are reviewing their urban planning, with nostalgia of former times with boulevards, parks, and orchards. In cities like Madrid, the horizon 2024 looks forward to neighborhoods with fewer cars and grand boulevards with the idea to remedy previous urban planning policies (García B. (2013).

Other major cities (Tokyo, New York, Chicago, London) look at the future in a similar way.

The new urban horizon obliges public authorities and institutions to respond to social demands with several actions: the improvement of the environment, conservation of natural resources, food supply and reduction of waste, energy consumption, carbon footprints and water management for a blue economy (Pauli G. 2013).

To meet these social demands, urban agriculture is one of the key instruments. However, its development is facing a series of challenges, among which the following can be highlighted:

- Spaces available for their implementation, either on the ground or built high up (terraces, façades, balconies)

- Improvement of yield and quality control

- Efficiency in the urban food chain

- Adaptation of urban plans to new social demands

To respond to these challenges, cities have to innovate in various scenarios:

4.1 Technical scenario

In addition to the appropriate building construction and techniques adapted to farming activities, the key is to improve productivity and quality.

The improvements of agricultural practices include substrates, appropriate plants, permaculture, bacteria, algae, fungi and the tendency towards organic farming.

Intensive agriculture also relies upon crops in greenhouses. In countries with warm climates, the results are very positive in up farming (terraces, balconies, walls). However in cold countries the situation is not as easy. It is here where innovation can lead to greenhouses that reuse gases emitted into the atmosphere for central heating in buildings and factories.

Thus, several objectives of the blue economy are met. The heat source of the gases used in the greenhouse also decreases the harmful effects of the "heat island" faced by many cities. The fixation of carbon by plants, their release of nitrogen and sulphur fixation treatment reduce the atmospheric pollutant effects.

Hydroponic crops constitute a good alternative in UA, where available space is limited. Plants grow in water, resting on a substrate that can be of different materials (wool rock, coconut, among others). Water is provided manually by gravity or other forms. Nutrients can be based on recycled or composted urban materials. Also, they can be combined with other productive systems such as fish farming, therefore resulting in a closed cycle. Fish waste such as that from tilapia serves the hydroponic system, which in turn partially recycles ammonia for farming (Red One Blog 2009, Mendizabal, 2013).

This practice is increasing in modern cities. Urban hydroponic crops can supply organic food and healthy products throughout the year (Smiechowski J. 2013).

The expansion of these crops, with optimal innovations can reduce their costs if they are operated in economies of scale. They may recycle their own wastewater, which, when duly treated, decreases the water needs, although we must also pay attention to quality control to avoid health problems.

4.2 Bureaucratic - administrative scenario

The establishment of urban planning rules and contractual agreements between owners and users of the land may facilitate the normal development of the UA by eliminating the uncertainties for both parties.

UA has been a traditional activity for centuries and it has inertia and peculiarities that have enabled it to survive without official support and aside from urban regulations. Its individualistic nature has made its aggregation and capacity to pressure on official institutions difficult. It moves between illegalities, lack of services, hygiene controls what may lead to problems, which are always very localized because they essentially affect the users themselves.

Therefore, urban society has to facilitate initiatives, promote UA organization, biodiversity, the environment, sustainability and landscaping programs.

International cooperation may show how UA has been developed in other cities, successfully or not.

As we have seen, the modalities that can be offered by UA are varied, but there are common denominators; the socio-economic,

Brooklyn Grange's farm. Brooklyn Navy Yard,. Source: Greenroofs.com; Photo Courtesy of and CroofliteR, Skyland USA.

ecological and urban development dimensions where bureaucracy may play an important role. Among others, we can mention the following (Drescher A.W 2000):

- Use of buildings, terraces, facades, interiors and balconies for orchards
- Family and community gardens, patios
- Recyclable orchards in landfills and dumps
- Secondary use of public and institutional land (tram routes, railroads, schools)
- Ventures of public and private capital that allow joint managing by municipal consortia, state entities, communities of neighbors, and individual or associated farmers.

4.3 Economic - business scenario

Efficient urban agriculture represents partial food self-sufficiency. Farming has positive effects in labor market and social relationships, and improves nutrition levels with the supply of fresh produce throughout the year.

Intensive or industrial UA can be achieved through greenhouses located in available urban plots, roofs or buildings built specifically for that purpose.

These greenhouses can meet several objectives: the production of ornamental plants and food vegetables for sale in the city and the reuse of chemicals (carbon, nitrogen) emitted into the atmosphere by factories and buildings, polluting the environment and causing the "heat island" in urban environments.

Productivity in greenhouses can increase through a good management and appropriate technologies such as the use of LEDs which control light intensity for the crops. During the light phase, plants capture solar energy; the water molecule breaks, sugars are synthesized and oxygen is ejected.

In the dark phase, plants capture the CO_2 to convert it into sugars, which accumulate more complex sugars and synthesize starch and other structural polysaccharides (cellulose). For this reason, plants can work without being permanently lit.

The light intensity of a crop depends on the temperature, humidity of the substrate, environmental conditions and solar radiation. These variables are controlled with electronic

Greenroof in France. Source: Greenroofs.com; Photo Courtesy of Vegetal i.D.

devices (dimmers), allowing for adequate management of the production process.

Renewable energy sources can be diverse. One of them is the reutilization of gaseous waste expelled by central heating of buildings or factories. Another one is photovoltaic solar panels frequently positioned on the roof of the greenhouse.

All these actions increase the perspectives of business and investments.

4.4 Environmental and educational scenarios

The environmental impact of green buildings is evident. Several studies show that one square meter of plants reduces the thermal gradient by 5ºC, captures about 50g of CO_2 per day, produces the oxygen needed for a person to breathe for a year, reduces air pollution by 130g of particles and the acoustics by around 10 decibels. The impact at the global level in a city may be calculated according to the potential greening areas available. Energy saving is another important effect. Thus, experimental research of green roofs in a Mediterranean climate showed that during summer time if there is dense vegetation, the thermal gain which enters the roof diminishes by about 60 per cent and the outgoing energy is 9 per cent greater that the incoming energy. In fact, the thermal energy behavior is 4.8 for the substrate and 7.2 per cent for the vegetation (Olivieri, F et al., 2013).

However, green values are beyond the concern of the built and natural environments. They are related to education, social justice and economic development.

Two decades ago (Brown V. 1993), some of the most significant indicators for an urban environment included: urban farming, land use, transportation, air quality, socio-cultural activities, flora-fauna regeneration, economics, safety and health.

Toronto green roof. Source: I. de Felipe.

Some basic questions about future green cities are related to the degree of self-sufficiency and their sustainability. It is difficult to provide figures on self-sufficiency because it depends on the size of the city, consumer habits and type of products. In any case, urban and rural areas are complementary in relation to sustainability of local economy (Roelofs J. 1996).

Wealth is generated in some basic ways:

- Making more with less
- Making something new
- Making the money go around
- Making something ourselvez
- Trading with equal partners

The implementation of an UA-integrated urban environment requires following formal rules, which, according to experts (Drescher A.W 2000), should include the following elements:

• Develop an institutionalization system of the activities and functions that are needed to manage various interest groups (builders, landowners, urban farmers and neighbors)

• Provide a legal framework to current and potential activities to be carried out by AU

• Regulate clearly the system of access to productive factors such as water and land

• Institutionalize the administrative procedures allowing both access to the land and verification of commitments and contractual relations

4.5 Innovation management scenario

Innovation management concerns the way urban farmers are organized, their associations, and improvements in agricultural practices. The commercial aspects can be included in this chapter and include ultra-short organized commercial circuits, markets of urban agriculture, and selling to restaurants and neighborhood communities.

This also requires innovation in regulation techniques and urban plans covering existing and available green spaces.

4.6 Social wealthfare scenario

The contribution of green cities to social welfare can be analysed from various positions. Socio-economic development is an instrument of improvement for citizens but it is not an end by itself; it should be completed along with other actions, which are not always well-defined. Technological advancement is usually considered positive, but there are questions of whom, when and what items are needed or should be replaced in our environment.

The well-known philosopher Bertrand Russell used to say that the change that produces innovation has a scientific essence. In this

Green roof farm. Toledo. Spain.

A greenroof in Brest, a city in the Finistère département in Brittany in northwestern France. Source: Greenroofs.com; Photo Courtesy of Vegetal i.D.

sense, while change is inevitable, progress can be problematic.

Therefore, the changes that are taking place in our cities, with masses of glass and cement and a large accumulation of people who depend on external resources for their sustainability, respond to certain social demands but do not increase the net value added, which is what it is required to progress.

The basic idea of the green city should accomplish the following requirements (Rasmy M. 1990):

- It is not completely dominated by and for humans.

- It is a city of the 3Rs (reduce, recycle and reuse)

- Self-sustainability

- Relationship of support among all the elements that compose it

- Availability of spaces, parks, gardens and other green areas and adapted environments with birds and animals

- A conserving city, based on minimal needs and elimination or reduction of waste

- Clean and healthy city with minimal pollution

- Humans, nature, technology and material will be harmonized in an "aesthetic relationship" where design colors, shapes and sizes will be based on natural relationships

- Cultural environment, with museums and artistic activities in places and public buildings that promote friendship and social relations among its inhabitants.

5. URBAN AGRICULTURAL POLICIES

Urban policy choices and research programs have to be reviewed according to the newly evolving trend in urbanization.

Food insecurity and environment degradation are some of the problems and community actions should focus on urban agriculture, health, employment, access to credit, subsidies and transfers, public works and feeding programs (Von Braum J, Mc Comb J, Fred BK, Pandya R. 1993).

To improve food security, some policies should focus on urban farming guided by local administration (adequate regulations, providing services), community organization and NGOs and national and international actions with policies to stimulate development.

Food security policies, in both the short and long runs, have effects on prices, employment and incomes, which influence the speed of the migration process from rural to urban areas.

One of the main questions to be discussed in the EU is the possibility of establishing an urban version of the Common Agricultural Policy (CAP) focused on rural areas. Considering that urban areas will contain 80% of the population in the coming two decades, the political power of urban citizens may demand special attention for greening cities. Countries, such as China, are changing their urban and energy growth models. New cities have green urban planning and traditional energy sources (coal) are being substituted by renewable energies and city efficiency programs.

Thus, the Common Urban Agricultural Policy (CUAP) may establish guidelines on a voluntary basis and the first step may be adopted by a pioneering city group.

The goals of the new CUAP should have priorities in improving citizens welfare, with food security and safety, health, and environmental considerations.

Some of the activities to be developed are:

- Urban planning and regulations on the use of food in agriculture and gardens

Roof urban agriculture in Bucheon. Korea. Source: Heejung Youn.

- Subsidies and tax benefits to promote green areas

- Bureaucratic facilities for buildings and organizations including green areas

- R+D+i programs for energy savings, environmental improvement, healthy activities and use of spare locations

- Extension services and formation courses for urban farmers

- Promote general food subsidy programs through:

    • Selection of food items consumed by poor people
    • Distribution of coupons or stamps on a household income basis
    • Subsidizing input for urban farmers

- Provide facilities for urban agricultural products:

    • Urban farmers' markets
    • Special distribution sections in retail stores
    • Quality control and certification systems
    • City trade marks
    • Promotion and publicity programs

Previous experiences with food subsidies and programs show problems with leakage and corruption when reaching target goals. Therefore, close supervision and management is needed, which, in some cases, may increase costs and bureaucracy.

In this way, community development initiatives should be combined with self-help initiatives for the construction, maintenance and improvement of urban infrastructure. Investment in construction and maintenance costs may be reduced with the participation of the community and social movements, establishing the basis for social organization of the citizens, especially for newcomers who lack roots in urban areas.

However, for decades, household gardens and small animal production have been discouraged for ideological (rural habitats do not belong in the modern urban way of life) or aesthetic reasons (the glass and cement look of new buildings). The new concept of modern cities is more in favor of green cities, where urban agriculture is the corner stone.

6. LOOKING AT THE FUTURE OF URBAN AGRICULTURE

Urban agriculture has been alive in many cities for years. However, in the last few decades we have experienced special movements to improve agricultural practices around the world, especially in big megalopolises (London, Berlin, Chicago, New York, Mumbai, Madrid and Mexico) (Briz J, De Felipe I. 2013)

There is an urgent need to design a sustainable urban life, and agriculture is part of the solution. Nevertheless, there are political restraints dealing with laws and regulations, urban planning, land property rights, inadequate organization of urban farmers, low implementation of environmental technologies and supportive services that should be overcome. In the coming future, attention should especially focus on:

Roof urban agriculture. Agro Paris Tech. Source: I. de Felipe.

Roof urban agriculture. Paris. Source: I. de Felipe.

6.1 Promotion of Urban Agriculture

Marketing promotions are needed to inform and convince the citizens of the positive effects of urban agriculture at several dimensions: environment, food supplier, health, landscape, natural resources, recreation areas and socioeconomic activities.

We suggest to citizens that it is important to grow food by themselves to build social relations with neighbors and friends.

Community-supported agriculture creates a new situation where the participants may visit their orchard and participate in the cultivation and harvesting. Local consumption may be lucrative and may establish mutual agreements between growers and other consumers.

6.2 New Urban Agricultural Policies

Rural development has the benefit of Common Agricultural Policy in the EU, which considers the strategic importance of agriculture. However, urban planners have focused on transportation and housing without paying any attention to green areas and agriculture. Instead of maximizing short term profits they should look at the long-term, including sustainability and use of local resources.

Idle land that formerly supported buildings and old construction projects may be recycled into new farming areas. Therefore, public and private forces have to coordinate new actions. For a certain period of time, municipal regulations may facilitate the temporal use of land for farming through local legislation where the interests of owner and users may be warranted.

In a similar way, up farming may be accepted in buildings (terraces, facades, balconies and indoors), with special assessment and education programs.

Technical restrictions, such as damage caused by plant roots or added humidity in the buildings, or landscape modification in cities with special recognition of historical inheritance, may be avoided. Municipal regulations can regulate quality of the construction and urban planning. Simultaneously, there are programs to support seeds, services and plants for UA farmers and designers, in order to reach a harmonization of the landscape, in terms of colors and food for the neighborhood.

6.3 Urban agriculture extension services

While rural farmers have been trained in their agricultural practices by extension specialists and have great knowledge from them, at least in developed countries, urban farmers are newcomers to farming activities and the conditions are different. The soil and environment is quite different in urban areas due to the proximity to citizens. Agrochemicals have to be select and limited and organic agriculture is an interesting option. Varieties of plants, production systems and harvesting techniques differ between rural areas and cities and need special practices.

In countries such as Vietnam, the capital, Hanoi, has a group of extension people for urban farmers. Cities such as Havana have special consulting services for seeds, farming and other practices. Another chapter describes market information and training on environmental risks on wastewater treatment or rainwater management.

Good practices in urban agriculture have to be disseminated adequately through the news media, and involves technicians and policy-makers (Barrs Robert 1997). Opportunities to improve urban agriculture will benefit the ecology and sustainability of cities.

6.4 Promotion of local products

The interaction of food, health, ecology and agriculture has to be integrated into promotion programs. Citizens may appreciate their own products either as urban farmers or neighbor consumers. Advertisements like "NY products" or others should be accompanied by a local brand and label. Local agencies will have certification systems which guarantee the quality and local origin of the food. A specific case is the Urban Organic Agriculture oriented towards a specific consumer segment, with higher added value.

6.5 Ultra short food chains

Shortening food chains is one of the solutions to the inefficient food market supplied by distant origins, with high consumption of energy, water, ecological footprints and, consequently, big marketing costs.

In general, farmers and consumers, either they are small or middle size entrepreneurs, try to get involved in the task of skipping the middleman by using different strategies (E-commerce, farmers' markets and home delivery) which provide fresh and healthy products at reasonable prices. The cornerstones are logistical organization and the mutual trust between the actors.

In the case of urban agriculture, the situation is even better. The consumers are either producers or neighbors who may directly know the orchard and interact face to face. Thus, we promote ultra-short circuits with advantages in several scenarios based on the privilege of proximity.

7. CONCLUSIONS

For a better understanding of the role of urban agriculture (UA) in the evolution of greening cities we have to answer several questions about where we are coming from, where we are and where we are going.

The analysis of trends, human activities and environmental linkages provide important clues, such as the importance of designing adequate strategies and their effects on health, lifestyle, economy and the natural ecosystem of a city. Looking to the future, we need a management response by local administrations, NGOs and entrepreneurs. Environmental auditing for public regulations and policy analysis has to be in the agenda.

Urban agriculture has multifunctional dimensions. Besides the advantages we have mentioned, UA creates a socioeconomic network with employment opportunities, social and friendship interactions, enhanced biodiversity, improvement of environmental conditions, ecological services, education, recreation and leisure opportunities. Correspondingly, urban society has to respond to the need for greening life and look for a sustainable horizon.

The greening cities movement is a revolution to improve the future of our urban civilization, and UA is a basic element of it.

As a revolution, several changes have to be accomplished. To optimize social welfare, urban planning and its applications have to be adequately discussed by all the actors involved.

The challenge of UA in each city is to optimize the possibilities of using the idle land/space between buildings or up farming on roofs and walls. Urban planning has to balance the possibilities and limitations with the political environment, identifying the different groups of urban interest, their bargaining power and social justices. Quite often there are significant differences and conflicts. On the one hand, we have strong groups of builders, real state, political and financial lobbies, and on the other hand, the neighborhood associations, green movements, individuals and urban farmers. However, there are convergent movements and, in some ways, synergies between them, such as the corporate social responsibility and the idea that welfare may be compatible with economic profit.

The time is ripe for citizens to do the right thing in green urban actions.

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CHAPTER 9
SKYRISE GREENERY: THE SINGAPORE STORY

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ABSTRACT

Today, Singapore, a city state island of just over 700 square kilometers, takes pride in having sky gardens and vertical green walls covering more than 500 buildings and about 60 hectares of green roofs. This article captures the journey of such achievements.

KEY WORDS

Green, skyrise, Singapore.

1. A 5-DECADE JOURNEY, AND STILL MOVING ON

From a humble and symbolic act of planting a tree, Singapore transforms itself from a Garden City to the City in a Garden within five decades. The journey started with the planting of a Mempat tree on 16 June 1963 by the then Prime Minister of Singapore, Mr LEE Kuan Yew, to mark the inaugural Tree Planting Day. With that, Singapore started the Garden City movement where a rapid urban greening program and an urban planning approach in which greenery received equal, if not more, emphasis than the expansion of buildings and infrastructure. It was a conscious effort to reverse the deficit of greenery in a rapidly expanding city which Singapore was experiencing in the mid-1900s. Through the use of a variety of policy instruments and design guidelines and the development of institutions and political support, the city of Singapore is systematically transformed into a lush, verdant city. The journey is still continuing to unfold in Singapore and is now expanding into the vertical spaces of the city. So much so that the modern Singapore is truly a city cloaked in green, the tropical City in a Garden!

As urban and population growth continues, new urban greening policies and strategies need to keep pace with the change in the form, structure and character of Singapore. One of these steps that the city is boldly taking is the creation of an added layer of greenery in the elevated plane through the placement of greenery on buildings and infrastructure. Numerous high-rise greenery installations are already visible in the city, a few of which are pioneering efforts that are more than two decades old. The majority show the recent progress in bringing greenery onto buildings. These take the form of rooftop gardens, green roofs, sky terraces, landscaped balconies and green walls.

2. SKYRISE GREENERY – UNIQUELY SINGAPORE

"Skyrise greenery" is a term that has gained popular usage in Singapore, amongst policy makers, architectural and building professionals, and members of the public. A term coined in Singapore and unique in Singapore, it refers to "nature on superstructure" or greenery that is incorporated onto buildings or structures above the ground level. It has found its way into government documents, popular literature, blogs and even in the first encyclopedia on Singapore and is befittingly, a Singaporean invention that reflects the national attention on greenery in the city.

The origin of the term can be traced to a series of Skyrise Gardens Exhibitions that was first organized by the National Parks Board (NParks) and the now defunct Parks and Recreation Department in 1992. The exhibitions were conceived as an outreach effort to encourage Singaporeans to take up gardening in high-rise apartments, where more than 85% of the Singapore population lives. Subsequent exhibitions were held in 1995 and 1998 and the exhibition series culminated in the last exhibition in 2001, which was held in conjunction with the International Federation of Landscape Architects World Congress and Exhibition. The event attracted more than 100 000 visitors. It was during this exhibition that the concepts of vertical green wall and rooftop farming were introduced to the public.

While "skyrise greenery" has its origin dating back two decades in Singapore, its wider adoption in Singapore did not materialize until the mid-2000s. It was only in the early 2000s that a more coordinated effort emerged through the work of public sector agencies, key entities among which are the Urban Redevelopment Authority (URA, NParks and the Ministry of National Development (MND) under the guidance of the Garden City Action Committee (GCAC)[1]. In developing the character of the Garden City, greening of the high-rise environment, particularly buildings, emerged as one of the key ideas, with extending the green ambience of the city vertically as the dominant objective.

Skyrise greenery progressively gained impetus as a form of green architecture feature and provided a means to both improve building performance as well as to mitigate the impacts of the building on its environment. The importance placed on the role of a green environment also created an added emphasis on skyrise greenery as Singapore became denser in its urban character. Skyrise greenery was seen as a means to ensure that "city dwellers are never far away from greenery even with urban growth and high density living" and that "Singapore being land scarce, greenery can be pervasive in our urban spaces, be it, within the public or private realms."[2] In the late 2000s, the promotion of skyrise greenery was also done to demonstrate how "skyrise greenery contributes effectively in balancing competing demands between development and nature in a compact city."

Commencing in the late 1990s, Singapore's largest building developer, the Housing and Development Board (HDB), introduced multi-storey car-parks to free up land on the ground previously used for surface car-parks; and rooftop gardens were also introduced to the topmost deck of these multi-storey car-parks to reduce heat and glare from the otherwise concrete-covered structures. HDB, has to date, greened up 108 out of around 500 4 multi-storey car-parks in housing estates. Part of the effort is dedicated to using green roofs on the top parking deck of multi-storey car-parks, with an estimated nine hectares of green roof to be added between 2010 and 2013.

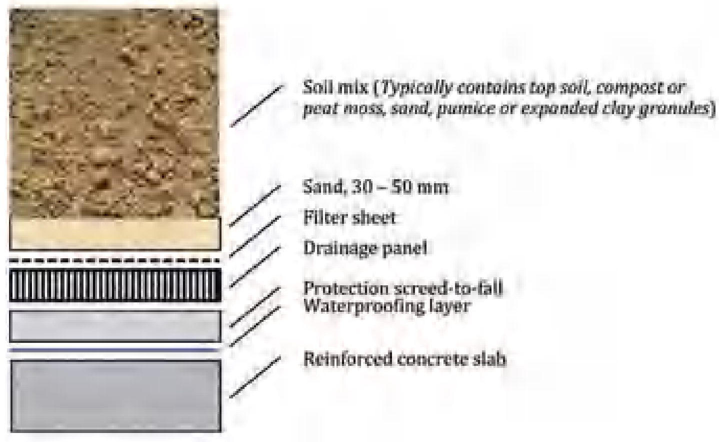
3. ROOF GARDENS AND GREEN ROOFS

While "intensive green roofs" and "extensive green roofs" prevail in the Western world to depict the two extremes of skyrise greenery, Singapore chooses to adopt "roof gardens" and "green roofs" to depict the same.

Roof Gardens

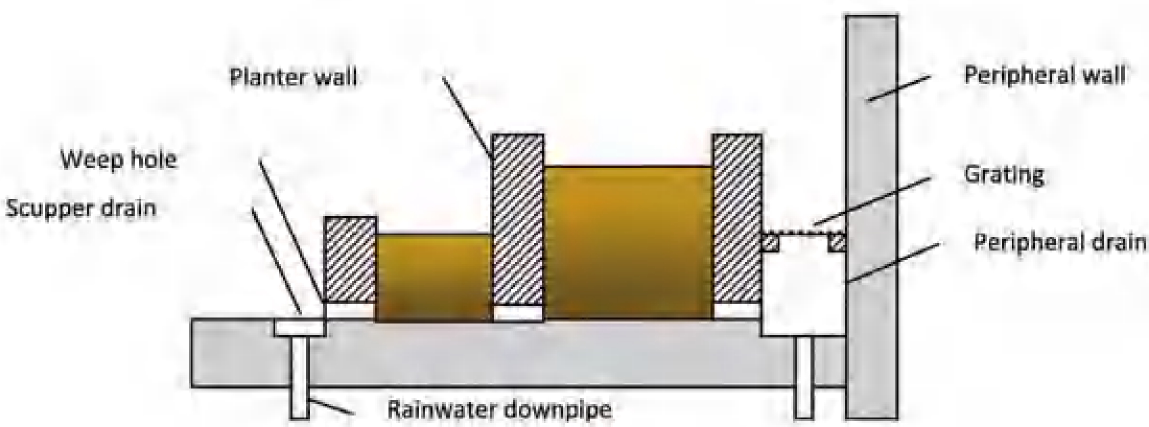
Roof gardens function as the elevated new "ground level" that link every block of apartments and provide convenient access to greenery, recreational space for the residents. Regardless of age, race or gender, the roof garden caters for all. As such, it is common to find features synonymous with children's playground, exercise equipment, benches and shelters, vegetated trellises, foot reflexology paths, hanging hooks for bird cages amidst lush greenery that provides shade and coolness to the micro-climate up on these roof gardens.

A TYPICAL BUILD-UP OF A ROOF GARDEN SYSTEM IS SHOWN BELOW



The most common form of containment for the roof garden system is the planter box. Such planter boxes, of a variety of shapes, ranges in its depth from 400 mm to 1200 mm to cater for a spectrum of vegetation from grasses to palms and trees. Excess water is drained from the planter boxes through weep holes that are located at the bottom of the planter walls. From the weep holes, water then finds its way via gravity to the peripheral scupper or surface drains before discharging from the roof through the rainwater downpipe.

DIAGRAM DEPICTS THE RELATIONSHIP BETWEEN THE PLANTER BOX AND DRAINAGE



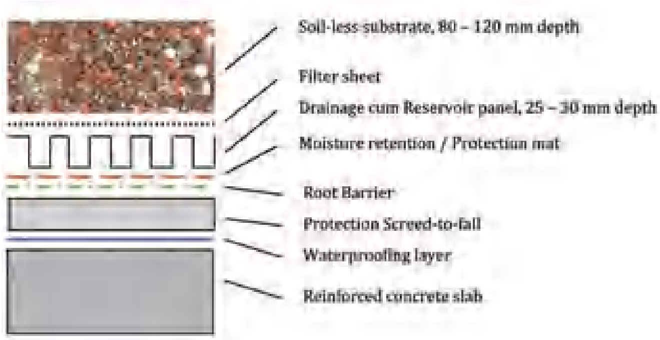
Green Roofs

While pockets of green roofs are implemented on roofs of residential blocks, majority of the green roofs are on multi-storey carparks. Two forms of green roof systems evolved through the years and typify the Singapore scene – the layered system and the modular system.

The green roof journey started in 2003 when HDB, together with NParks and the National University of Singapore (NUS), initiated a pilot project to test out four different layered types of green roof systems (two of which originated from Germany and the other two were locally assembled) over a period of 18 months. The roof of a particular multi-storey car park in the Punggol public housing estate was selected to be the common test site for the green roof systems. A series of analytical tests by NUS were carried out and they validated the benefits as claimed by green roofs in the western world. By the end of the trial, the same site and for the same objective, was given over to test out a local innovation – the modular green roof system; and the results were similar to that of the previous. Henceforth, green roofs took off in Singapore.

Typical roof gardens on top of multi-storey car-parks at the Punggol public housing estate in the north eastern part of Singapore.

THE TYPICAL BUILD-UP OF THE LAYERED GREEN ROOF SYSTEM IS SHOWN BELOW



THE TYPICAL BUILD-UP OF THE MODULAR GREEN ROOF SYSTEM IS SHOWN BELOW

Though the range of vegetation suitable for green roofs in Singapore is not as wide as that for roof gardens, the number of plant species that are hardy, drought-tolerant, and require little maintenance exceeds thirty! A good resource for such plants are found in the publications by NParks –

1. A Selection of Plants for Green Roofs in Singapore, by TAN Puay Yok& Angelia Sia, 2nd edition (2008), ISBN: 978-981-07-0052-2; and

2. 1001 Garden Plants in Singapore, by BOO Chih Min, Kartini Omar-Hor and Ouyang Chow Lin, 2nd edition, 5th print (Jul 2010), ISBN: 981-04-9268-5.

Photo shows the current condition of the first large scale green roof on top of a multi-storey carpark, implemented by HDB in late 2007, in the Sengkang public housing estate using the layered green roof system.

Photo shows a green roof implemented in 2009, also in the Sengkang public housing estate using the layered green roof system; contrasting with a traditional multi-storey car park that is without vegetation at the background.

Photo shows a green roof being implemented in a more challenging condition – on top of a barrel-shape metal roof. This green roof resides above the weight training room at the Senja-Cashew Community Club in the Bukit Panjang public housing estate.

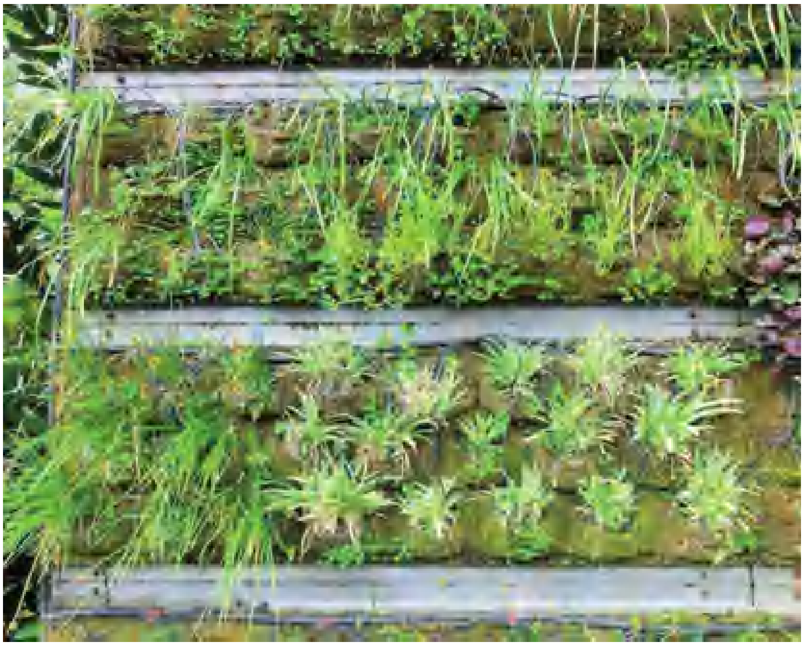
Photo shows a green roof on top of a long and narrow metal roof construction of a link bridge at a coach park on the Sentosa island, an iconic tourist destination that is off the main island of Singapore.

Photo shows a green roof that uses the modular green roof system on top of a multi-storey car park in the Tampines public housing estate. Though the greenroof is inaccessible for the public, it is highly visible to the residents living in the surrounding blocks of apartments.

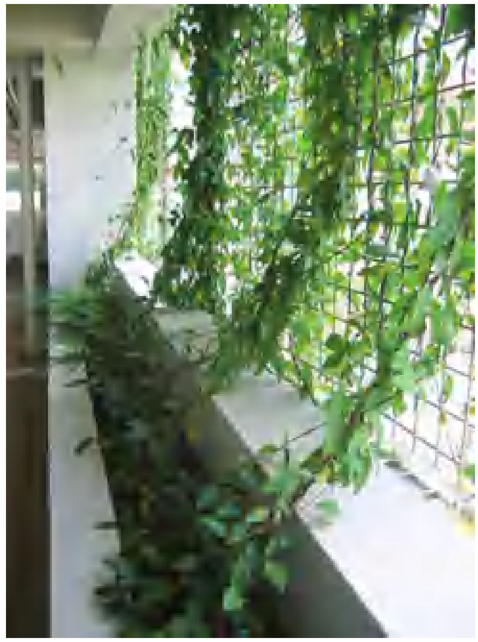
The photos show the four main and most common types of greenwall systems found in Singapore.

4. GREEN WALLS

Similar to the beginnings of the green roof journey, the research arm of NParks, the Centre for Urban Greenery and Ecology (CUGE), initiated a project together with NUS to examine the performance of eight different greenwall systems at the Hortpark in

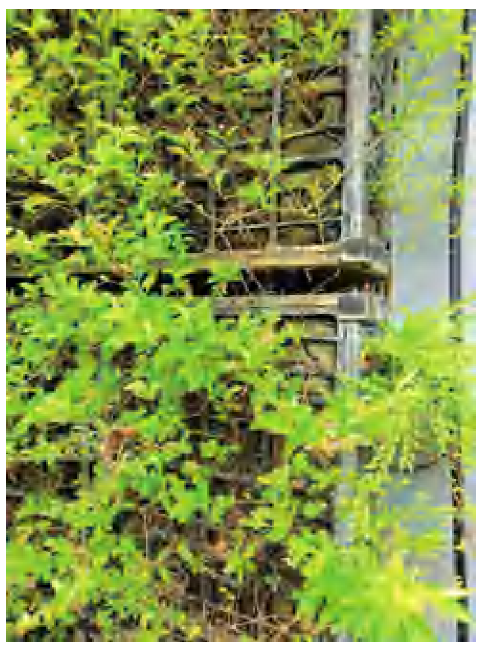


Greenwall system – Pocketed panels



Greenwall system – Planter box & Mesh

Greenwall system – Mini potted plants



Greenwall system – Box modules

Singapore in 2008. Each of the greenwall systems were implemented on a concrete wall of six metres in height and four metres in width. A series of examinations including that relating to thermal properties, plant growth and water consumption were conducted by NUS. After the conclusion of the project, CUGE published its preliminary findings in booklet titled, “Introduction to Vertical Greenery” by Derek Chan and Kelly Chiang (2008, ISBN no.: 978-981-08-1623-0).

In terms of forms, the following types of greenwall systems prevail in the Singapore scene:

1. Planter box and cables/mesh

2. Box modules

3. Pocketed panels

4. ‘Mini-potted plants’

5. KEY POLICIES PROMOTING SKYRISE GREENERY IN SINGAPORE

In 2009, the Singapore government announced through its sustainable development blueprint developed by the Interninisterial Committee on Sustainable Development that it has set a target of adding 50 hectares[5] of skyrise greenery to Singapore’s skyline by 2050, and an intermediate target of 30 hectares by 2030, adding to the impetus to accelerate skyrise greenery implementation.[3]

Underpinning such an ambition are key policies such as:

1. Gross Floor Area (GFA) exemption for sky terraces (1997, revised in 2007) – The area of the sky terrace within a forty-five degree line taken from the edge of the overhead projection enjoys GFA exemption.

2. GFA incentive for balconies (2001, revised in 2007)

3. Guidelines for landscape deck (as an added layer of green created on a roof) in residential flat and condominium (2004)

4. GFA incentive for planter boxes (1989)

5. GFA incentive for outdoor refreshment area on rooftops of existing buildings (2009)

6. Landscape replacement areas within new developments (2009) – This mandatory greenery replacement policy requires developments to replace the original green area in new developments.

7. Skyrise greenery incentive scheme (2009)

6. CHALLENGES FACING SKYRISE GREENERY

The remaining challenges that Singapore faces today are mainly two folds – firstly, moving away from the being overly focused on the aesthetic appeal of skyrise greenery but to harvest its functional and sustainable benefits; and secondly, tackle the high labour cost versus productivity of implementing and sustaining skyrise greenery.

However, such challenges should not impede progress because there are existing strengths. Instead, it should heighten our awareness of possible ecological costs of landscape, and spur us to greater ecological consciousness in design and research to develop better tools for landscape design.

Riding on the growing momentum, it is timely now for Singapore to look for a more aggressive target in skyrise greenery attainment. After all, “we make life at the top ... beautiful!”

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2. National Parks Board (NParks) and Urban Redevelopment Authority (URA) Press Release "A Lusher and Greener Singapore. URA and NParks introduce schemes to promote Skyrise Greenery", 29 April 2009.
3. Interministerial Committee on Sustainable Development, "A Lovely and Liveable Singapore: Strategies for Sustainable Growth", (Singapore Ministry for Environment and Water Resources and Ministry of National Development, 2009)
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CHAPTER 10
URBAN GREEN AND HUMAN HEALTH

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ABSTRACT

It is important to prepare for a city, the space which can be safely walked in comfort. In the city in Japan, pleasant walk space with sufficient touch to come to walk has been indicated that few things are problems. It is a matter of course that it is also important for a city dweller's health maintenance to take the measures which control summer heat-ization of the city using evapotraspiraion of water by underground osmosis of rain water, promotion of tree planting, etc. until urban land use plan or green space planning achieves effect. It is required for an improvement of city airborne environment to consider appropriately arrangement of a green tract of land, the scale of a green space and plants selection until it can perform removal of a causative agent. Research and development about maintenance of biodiversity, preservation of the green tract of land which builds a healthy city from a viewpoint of construction of the cyclic system of city environment, and creation are desired. The green which exists in urban space brings a particular reaction to a city dweller's mind and body, and it can be said that the many cases show the stress relaxation effect. In the city which changes to an aging society, it becomes important for various kinds of life space, public space, working space, hospitals, elderly-people institutions, etc. to arrange suitable green space for each city.

KEY WORDS

Visual landscape, physical stress, chemical stress, biotic stress, QOL, green effect

1. INTRODUCTION

Health is when the mind and body are not sick, or is the state of mind and body which leads to recovery when sick. The contrary concept of health is the state where there is stress rather than sickness. The direct and indirect factors an illness are the results of stress. Both lifestyles and living environments can be stressors.

Also, in time and in space, the most typical stressful living environment is the city environment. There is probably no objection to this.

That tracks of green spaces are related to the city environmental agents that produce stress experienced by peoples' minds and bodies is an experimentally known fact.

There are many intricately related elements, which bar health in the living space that surrounds city dwellers. For example, an environment of summer heat, and air pollution substances. are stressors which threaten the health of the body, among others. There are more positive opinions in the comments from

Tokyo has aimed at modernization as a capital in Japan till today since 1867. City planning of economic growth priority seemed to have succeeded, and population increased to 12 million people. What has been lost as a result were woods of a precinct yard place, and a garden of the daimyo's mansion. The city park area per head of the population is the lowest level in the major cities in the world. The stress brought about by city life is large. Roof gardens as public spaces in Tokyo. Public access by an outside lift. Source: M. Köhler.

patients and sojourners when the rich green view from the window of a hospital or a nursing institution for the elderly is more comfortable than a scene with many artificial elements. Many researches have just begun describing this.

Such institutions have seen researched the pattern that a green existence contributes to primitive perceptions and an improvement in citizens' quality of life (QOL). This has been reported in every country in the world.

The factor which contributes to active maintenance of good health is exercise of continued operation. It is because of this that a doctor will advise a patient to walk rather than use a car to raise bodily circulatory function and suppresses advancement of illness. From this viewpoint, it is important to prepare a city with space that can be walked in safely and with comfort.

In the cities in Japan, pleasant walking spaces have indicated that few things are problems.

2. UTILITY OF GREEN INFRASTRUCTURE ON PHYSICAL STRESS

Summertime heating of cities is progressing, exceeding the speed of global warming.

In Asian cities of the fairly-developed countries where modern city buildings and urban facilities have been built with iron, concrete and glass from the second half of the 19th century to the 20th century, city summer heating is notably increasing. Japan is not the exception, either. Small children and the weak elderly people are strongly influenced early on by the thermal environment of the city and can have severe physical stress. Even so, people in the prime of youth or middle ages are bad, considering this an affair for other people. It is because of this example that young or middle aged people who work outdoors have been increasingly taken by emergency transport due to heat stroke over the past ten years. It is believed that an effective and fundamental improvement to a city's summer heat environmental problems is to establish city planning, which controls the upper boundaries of city density, and to enforce it. Of course,for maintenance of city dwellers' health, it is also important to take measures which control summer city heating, such as using evapotranspiration of water by underground osmosis of rain water, promotion of tree planting, etc., until urban land use plans or green space planning achieves the desired effect, because the execution takes time. Cities that are trying to tackle this measure eagerly are increasing in number all over the world.

3. UTILITY OF GREEN INFRASTRUCTURE ON CHEMICAL STRESS

Summer city heating generates photochemical smog and causes health impairments. Decreased wind velocity in highly dense city areas contributes to rising temperatures affects wind direction, making it hard to diffuse photochemical oxidants. The damage caused by photochemical smog is acute and serious. There are many victims also among younger age groups, such as teens who play outdoors. These days, air-suspended particulate matter is observed in air-pollution substances, which brings about health impairments. There are volcanic ashes and blown sands, which are created automatically, and substance contained in car exhaust emissions, which is created artificially. A research report about the relevance of the degree of air pollution by these particulates and mortality rate, found that disease of the heart and lungs (circulatory organs) occurs. Remarkably, patients are increasing in number in the developing countries of economic development where ownership frequency of the car is quickly increasing. A defensive policy against generated pollution is the most effective. It has not yet been shown clearly whether morbidity can be reduced by air purification processes and urban greening or not. There is much research regarding which trees contribute to an improvement of the airborne environment of a city by absorbing and adsorbing various kinds of air pollutants, and diffusing them again. To improve the airborne environment of a city, it is important to consider an appropriate arrangement of green tracts of land, the scale of a green space, and the selection of plants so it can remove the causative agents.

A city requires green. Nowadays, the green necessity poses a problem of the earth level. Such campaign can be seen across city with a monument. This is a central city area in Nagoya.

The example the herb garden, which is the past property, had been opened wide into citizens by Japan modernization, and came to be used as a city park. Although this is a charged park, from the young person, it is loved by all generations and even elderly people are used for them. It is said that the combination of a lawn and a wood became an already international style by the typical design of the park. A city park contributes to city residents' health maintenance greatly.

4. UTILITY OF GREEN INFRASTRUCTURE AGAINST BIOTIC STRESS

The influences on the human body by chemical substances that cause pollen, house dust, substances of sick house syndrome, etc., and contribute to biological stress is expanded. Stress resulting from biochemical phenomena cannot be overlooked, either. Furthermore, serious health issues have also occurred. There is a possibility that infections that threaten human life may spread across the world at an accelerated pace. This is because the development of transportation has dramatically increased the temporal and spatial activity of a mass of human beings. In Japan during the past 4 or 5 years, we were anxious about the prevalence of West Nile fever, a new strain of influenza, and measures to help public health have been taken. Indirect factors of expansion of these infectious diseases are the ubiquitous distribution of population and population growth, such as the inequality medical standards due to economic disparities. Due to little urban green space, biodiversity decreases and interspecies competition between living things decreases, causing an unusual increase in the number of a specific kind of individuals. When these individuals carry a disease or germ and lack stability, the rate of infection can also increases.

It is expected that various living things, including infection, will become stressors for city dwellers from now on. Methods need to be developed that inhibit the action of living things that bring about such damage and evil or can not be controlled by chemical substances such as medicine. Research and development about maintaining biodiversity, preserving green tracts of land that build a healthy city from the viewpoint of construction of the cyclic system of the city environment, and creation are desired.

5. UTILITY OF GREEN INFRASTRUCTURE ON THE PERCEPTION OF THE VISUAL WORLD

Urban space can be described as having developed while destroying the green spaces that originally existed before human settlement. Assembled urban space is the artifact, and is

surrounded by food which has had the smell artificially removed and chemical substances added, and the convenient and comfortable life has been provided by keeping away from contact with natural objects. The 21st century is also predicted to have 70% or more of the population living in places that the world can call urban spaces. This will be something that has never been seen before in human history. It will be extreme and will easily bring about the formation of a new moral situation, which the population saw and consciously let pass. It can only say that it fears that the stress of city life is spreading all over the world. The only remedial action which eases this stress is the transfer of healing. It cures and city dwellers are requesting it in order to be cured. Healing techniques have been proposed from various fields and some have already been industrialized. Talking about the use of green infrastructure to bring about healing is the theme that is being discussed here in this short article. There is research regarding at the impact of both the artificial and natural environments and whether they are associated with a state of relaxation. Because relaxation is not uniform and there are differences in races or childhood experiences, this research into ways that green infrastructure affect relaxation has not yet been shown quantitatively.

However, it is not a mistake that research has shown that stress relief actions as a result of green infrastructure eases more stress in city dwellers. Conversely, the research that pursued the effects of greenery on the recovery environment from a fatigued state showed that the differences in green arrangements, green form, and contact distance with greenery have a difference on stress recovery. Moreover, in addition to the psychological approach, the paper about the scale method, describes a device that can measure a living body's reaction, developed as a method of measuring the degree of stress,

The construction of landscape by preservation of woodlands, planting of trees, flowers or green brings residents health and comfortable nature in a part of new town area. Such an apartment area attracts attention also as an investment outlet noting that it is popular among city residents and does not demote real estate value. The residential section good for health is excellent also in landscape. Tama new town, Tokyo.

The building of a school arranges the classroom on the south side in order to take in the sunshine of winter in a classroom. However, there are many days of intense heat in summer owing to the latest abnormal weather. It does not carry out that the inside of a classroom turns on strong air conditioning in consideration of children's health. Then, the green curtain was installed in outdoor and the schools which adopt the device that strong sunshine is controlled and the inside of a classroom does not become remarkably dark again have increased in number. The plants for curtain have been used as teaching materials which has a fruit and rapid growing like a balsam pear or a balloon vine. The morning glory has gathered popularity because of beautiful flower and easy care. This photograph shows the horticultural variety " ocean blue " of Sanda elementary school (Hyogo Prefecture).

and an objective verification has been attained. Moreover, medical research is becoming active regarding the degree of stress that can l be grasped from brain activity, or autonomic nerve activity measured as the amount of stress hormone generated, and how this influences immune function.. In the case where one rests in a few green parking lots versus the case where one rests in a green tract of land surrounded by a grove, it was shown that when one rests in a green tract of land, many alpha waves occur in the brain and one is relaxed.. This report is from the large filed of brain physiology. An experiment compared the brain waves generated when looking at a hedge with the brain waves generated while spending the same time looking at a concrete block wall, and found that many beta waves occur while looking at a concrete block wall but many alpha waves occur when looking at a hedge. That is, it showed that subjects were more relaxed when looking at the hedge. When a person goes into the shade, they experience a measurable change of feelings and when one goes into a leafy shaded nook created by plants, a more positive change is experienced than when the shade is produced by an artificial plant. Research has shown that brain activity has a healing effect from plants and a decrease in systolic blood pressure can be seen. Studies that have shown that there is an effect plants on healing have attracted attention.

When the pressure level of the wind and wavelength continues to generate approximately equal noise, and when a photograph of a landscape in which the quantity of greenery differs is shown to a subject, it is reported that mental noise stress is reduced as the amount of green in the vision increases. This experiment is actual proof of the effect of stress relaxation by greenery.

The research in the field of experimental psychology has also progressed. The green infrastructure that exists in urban spaces brings a particular reaction to a city dweller's mind and body, and it can be said that there are many cases showing the effect of stress relaxation.

6. IMPROVEMENT OF PHYSICAL HEALTH

One type of occupational therapy is horticultural therapy. The elderly care facilities that can perform this treatment have increased in number. It is said that horticultural therapy effects the improvement of mental and athletic ability, and research to verify this is advancing. People plant flowers or vegetables together as part of the fundamental work of gardening, including tillage of the yard, sowing, watering, bowl raising, fertilization, etc. Because some advanced work of harvesting, etc. is accompanied by more complex operations that include the legs, arms, fingers, etc., it brings about an effect of rehabilitation. Moreover, it becomes an active stimulus to the sense organs, such as sight, sense of smell, and tactile senses, and prevents dementia. Because few people hate flowers and vegetables, work through horticulture serves as a source of rich communication and effectively creates a more stable mental condition.

7. RESEARCH ON GREEN INFRASTRUCTURE AND HEALTH

Because the quantity and continuity of movement increases at places with green infrastructure, it is said that the rehabilitation effects in such areas are high. The necessary equipment is required for motivation and for wiping away negative thoughts that one is poor at movement As equipment, green tracts of land are more effective than an indoor sports gyms, and do not introduce other new stresses. In a city that is adapted to a changing and aging society, it becomes important for various kinds of living spaces, public spaces, working spaces, hospitals, elderly care facilities, etc. to provide suitable green spaces. Each city can try to set up such spaces and institutions, but the kind of green spaces that are most suitable for improving consciousness in the environment as well as the necessary quality and quantity of green space is not yet clear. For this reason, research and development are needed.

8. STRESS AND VISUAL PERCEPTIVE STIMULATION WITH GREEN INFRASTRUCTURE

When people see a scene, the chosen visual object changes according to the contents of the scene. In scene recognition, eye movement on a visual target becomes more active. Peoples visual confirmation differs when looking at a townscape with many artificial objects or a townscape containing many natural objects. Using this, researchers have conducted an experiment measuring how much stress occurs at the instant that the scene is changed. According to these research findings, it has been reported that stress changes with differences in an individual’s mental and corporal situation as well asan individual’s palatability. The report said there was no universal and general solution. For each individual, the degree differs between whether a traditional Japanese garden is more effective in stress relief than a British landscape-style garden.

9. HOSPITAL GREENING

In order to determine the relationship between greenery and health, it is important to find out how greenery is related. Moreover, the healing effects of plants has begun to attract attention. Research into the effects of treatment has started, and measures for fields such as a horticultural and plant therapy have also been proposed. Such measures have begun to be brought into the fields of both research and education. However, in hospitals, which return those who are not healthy to a healthy state, the type and amount of greenery that can effectively achieve this is unknown. There are not many institutions where greenery is available for refreshment space, a dual purpose waiting room and common space, or a space for medical workers.

When researchers tried investigating at a hospital, many hospitals answered that greening was important and required for patients or staff. However, it turned out that there is also the problem that management expenses for introducing and installing green spaces and the costs of actually maintaining the facility are difficult to obtain and are not enough for maintaining health. Moreover, it was pointed out that there are very few specialists in hospital greening.

In order to solve such a problem, the independent administrative agency, the National Hospital Organization of Japan, hammered out "The Garden Hospital" concept to summarize the state of hospitals in the 21st century. The plan expects to ease the mental stress of patients, family and visitors to the hospital, and also staff by enriching the outdoor and indoor green spaces of hospitals. However, because the concrete greening manual, etc. are not yet finished it has stopped at the conceptual phase. The courtyard and rooftop garden of the hospital are included in this concept, and it is expected that patients and hospital workers will be able to touch and come close to the greenery, which is quite important for maintaining their healthy life. Moreover, in the present system of medical expenses, although it is possible for insurance to cover medical treatment such as indoor rehabilitation, insurance companies are not likely to cover the costs of rehabilitation in an outdoor garden. Not accepting this treatment as a medical expense has become a cause of delaying the introduction of hospital greening. An improvement in the system is called for.

In advanced hospitals, the practice of horticultural therapy has also been used in the medical treatment of mental diseases. In such hospitals, the budget for carrying out maintenance and management of the green

Integrated concepts with a double glass system Tokyo. Source: M. Köhler.

spaces over a long period of time has been secured, and the plan for the maintenance and management of the vegetation has also been formulated. Furthermore, in order to support green maintenance management, they also have the idea to borrow the effort of the inpatients who live near. This is because the volition to improve a patient's social rehabilitation is promoted. To maintain the greenery in the semi-public spaces near a hospital entrance, the method of harnessing the energy of local volunteers from the city flowering and planning community is also effective.

10. PRACTICAL USES OF GREEN INFRASTRUCTURE IN COMPREHENSIVE MEDICAL CARE

Comprehensive medical care is considered the medical treatment that has unified modern medicine and alternative medicine. The target of comprehensive medical care is not only medical treatment of a disease but also relief from illness. This means maintaining health and increasing health. Therefore, the view of utilizing green infrastructure has been introduced.

In the field of environmental psychology, research is progressing about the healing effects of natural scenery. A famous result of this will be described. Ulrich (1979) showed that natural scenery is effective in intentionally reducing awful feelings and the feelings of love and joy increase when the experimenter used a colored slide or photograph. Moreover, the recorded number of postoperative days in the hospital were compared between patients whose rooms had a grove visible from a window, and patients whose rooms had a view of a wall of bricks. The amount of nursing care and the number of medications or painkillers were compared. It was shown that natural scenery contributes to good postoperative recovery. There is now a study to see if greenery speeds up recovering from the effects of stress, improves working efficiency of proofreading work that needs concentration, etc. The healing score is expected to be high.

The demonstration which is comparing the adiabatic effect by rooftop gardening or the fall effect of the room temperature by dry mist. Exhibition in the national urban-greening fair Maebashi City in Gumma. Prefecture. Photo show for the general public of the concern about such a little special thing is also high. Data shows that people's health consciousness is increasing not by dry mist but green roof.

Horticultural therapy is a process in which an individual realizes happiness through a plant or horticulture in a broad sense, and is defined as what is attained by both active and passive measures. Although the effects of horticultural therapy appear complex, it is said that is helps in mitigation of quiet recovery of physical functions, self-admission, social acceptance, peacefulness of the heart, stress relief and improvement of spirituality.

11. CONCLUSIONS

The effect of green infrastructure on the health enhancement of city dwellers

By exercising in existing green spaces, maintenance and reinforcement of physical strength is carried out, weight problems can be treated and can be prevented, and blood pressure and blood sugar levels can be normalized.

Sleep disorders can be treated by passing through existing green spaces because vegetation is effective in maintaining a circadian rhythm.

By relaxing in existing green spaces, one can reduce stress and can regain balance in the autonomic nervous system back to a normal state.

When surrounded by existing green space, spirituality is improved. When one realizes that one can live together with greenery, it becomes a natural feeling with natural vitality.

The effects of green infrastructure on the maintenance or enhancement of good health in sick people (i.e., patients) has been described. That is why it is easy to persuasively measure the effects of greenery. However, green infrastructure and health are not just important issues for healthy people. In the world, there are cities where the outdoor atmosphere is too cold for living or too hot for working. Even if green infrastructure is introduced in such cities, there is a limit to the power of greenery for improving an environment to a comfortable level. However, greenery is required even in cities with such severe environments. In severe environments, surviving healthily becomes the priority. In order for people to have the desire and endurance to survive, the effects of close contacts with greenery are valid particularly when the severity of the environment is large. It is because existence of what is called life, and a size are realizable. Rooftop gardening and an ecowalls are urban facilities where one can feel greenery most closely. When such green infrastructure spreads into city, the city dwellers can realize the joy of survival. For cities in the temperate zone, which the environment is not severe, it proves that greenery is still important to maintain a healthy city and that greenery is needed for a lively life.

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CHAPTER 11

BIOTECTONICS AND POSITIVE INCREMENTAL CHANGE: EMBRACING THE NEW ECO-URBAN

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ABSTRACT

The emerging shift of paradigm from sustainable to positive development implies that novel planning and management approaches are needed in order to augment urban environmental quality and enhance well-being in cities. This paper examines how the recent development of biotectonics in Bogota has set the conditions for positive urban incremental change to happen via new stewardship schemes, in contrast to conventional top-down governance approaches. Three points are addressed. 1) How urban incremental change has been driven by progressive implementations of biotic roofs and walls in Bogota, and how multiple local stakeholders have contributed to this positive transformation: academia, industry, non profit organizations and the local government. 2) How biotectonics can help attain the new city's goals set by the latest urban planning regulations. Contributions to the main physical structures of the city are analyzed: Main Ecological Structure, Structure of Functions and Services, and Socio-economic and Spatial Structure. Particular focus is given to provision of environmental services and creation of public amenities. 3) How the interplay of local actors engaged in the development of biotectonics motivated the formulation of ad hoc Biotic Roof Guidelines for the city. These official guidelines target the new eco-city aspirations by adopting a Co-evolutionary, Multi-functional and Multi-scale, approach. The main structure and contents of the guidelines are discussed.

KEY WORDS

Positive Urban development, Green Infrastructure, Urban Environmental Quality, Environmental services, Biotectonics, Green Roof Guidelines, Incremental Change, Eco-city Stewardship.

1. INTRODUCTION

As the second urbanization wave rises, so does a concern for finding ways to drive positive change in the megacities of Asia, Africa and Latin America[1]. Several cities with emerging economies have been recognized as reference scenarios, offering insights on how environmental and social challenges may be opportunities for fostering well being. The case of Bogota (the capital of Colombia and one of the largest metropolises in Latin America) has attracted growing attention worldwide for a number of initiatives implemented by local administrations over the last two decades: Alternative massive transportation systems, recovery and democratization of public space, comprehensive urban planning, cultural development, and application of climate change adaptation programs. In recent years, the practice of vegetated architecture (biotectonics[2]) has started to add to Bogota's transformation, motivating the creation of novel governance instruments and opening pragmatic paths towards positive urban development[3].

Driving incremental change in cities through biotectonics

The aspiration of augmenting environmental quality in cities is often associated with government actions and prescriptive top-down management. However, there is a growing consensus worldwide about the need to engage diverse sectors of society in the realization of this goal. This is particularly relevant for cities with environmental stress but deficient administrative apparatuses and limited budgets to counteract it. Over the last six years, the development of vegetated architecture in Bogotá has provided an action platform for multiple non-government actors to participate in the configuration of a healthier urban environment.

General interest in biotectonics was triggered after research conducted by academics, which determined basic technical parameters for application of biotic roofs in the local context[4]. Architects played the crucial disseminating role by acknowledging this technology as added

Green roof. Columbia. Source: A. Ibañez.

value for their designs and implementing it in a wide array of project typologies. Industries developed technical solutions and local supply chains for the growing demand. The success of early implementations motivated the creation of best practice guidelines and the inclusion of vegetated infrastructure in the city's environmental and planning agendas as a viable mechanism to mitigate the negative impacts of urbanization and strive for urban environmental quality.

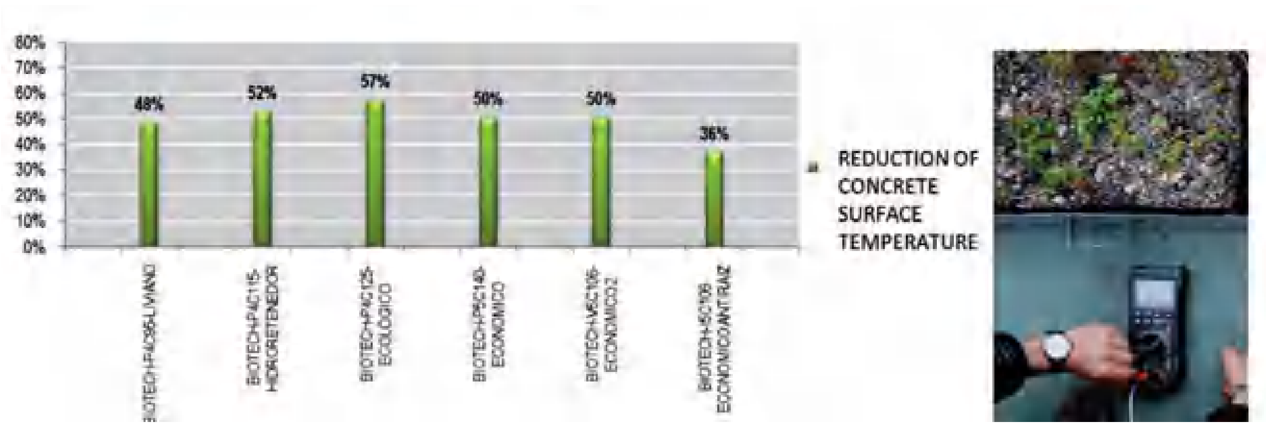
Vegetated infrastructure embraces knowledge from various disciplines, as it is essentially about finding the right interfaces among dissimilar aspects, mainly; living components, inert building elements, and environmental conditions[5]. Landscape or horticulture-related fields have usually provided the leading standpoint and integrated other fields into the process of developing these hybrid systems around the world[6]. However, in Bogota, the pioneer research on biotic roofs was conducted under the optics of building science, which considered biotic roofs as *tectonic*[7] components of buildings.

Investigations of local applications started in 2006 with an empirical study in the Master of Construction department at the National University of Colombia[8]. One hundred and seven tests were conducted on 30 experimental modules having distinct extensive biotic roof[9] configurations to determine the technical parameters of low-weight and waste from local materials. Functionality of components (draining systems, growing media and green cover) was tested under the climatic conditions of Bogotá[10]. From preliminary findings, six biotic roof systems were proposed for alleviation of specific environmental problems in critical urban areas. Their potential to provide environmental services was estimated by measuring four performance parameters: Thermal isolation, acoustic isolation, water retention capacity, and reduction of storm water discharge rate (Figure 1). This initial investigation motivated interest in this technology in other cities[11], and provided a technical baseline for further academic work[12], specific research[13], enterprise development[14], creation of non-profit organizations, and formulation of regulations for best practices.

Green roof. Columbia. Source: A. Ibañez.

Since the installation of the first self-regulated[15] biotic roof in 2009, the number of projects has been increasing yearly in Colombia, particularly in Bogotá[16] (Figure 2). Implementations in new developments accounted for 81.27% of the number of projects intervened with Biotectonics, and retrofit projects for 18.73%. By the end of 2012, the total area of building surfaces greened (biotic roofs and walls) had reached 60,000 square meters. Three building uses contributed the most to increase the vegetated surface in urban areas: Commercial (38.6%), office (18.5%), hotels (8.5%) and institutional (7.5%)[17]. In absence of public incentive policies, architects played a significant role in spreading the technology. The collaboration between researchers and designers in the early applications resulted in a diversity of projects and local expertise in integration of living systems with other building components[18]. The growing area of vegetated infrastructure

FIGURE 1. THERMAL ISOLATION OF DIFFERENT EXTENSIVE GREEN ROOF SYSTEM. A IBAÑEZ



in the city has progressively brought a number of environmental benefits[19] (removal of air pollutants, reduction of storm water runoff, waste recovery, reduction of heat island effect and increase of natural habitat area for local biotic communities).

These bodies of local expertise came together in the non-profit national green infrastructure network RECIVE[20], which was created in 2011 with the purpose of "promoting the development of Green Infrastructure in Colombia as 1) a responsible practice that enhances environmental quality and promotes well-being, 2) a long-standing feasible technology to be applied in the local context, and 3) a successful and sustainable market". To achieve this objective, a multidisciplinary group organized into committees[21] conducts activities in five strategic lines of action: 1) Promotion and education, 2) National database, 3) Assessment and certification, 4) Technical Advice, and 5) Innovation and development. The network has accompanied a number of government entities in the formulation of local regulations, guidelines, and local programs promoting biotectonics[22]. It has also been a platform for bridging knowledge with other national networks[23] and academic institutions overseas[24].

2. TARGETING ECO-CITY PLANNING ASPIRATIONS WITH BIOTECTONICS

Colombia is considered a leading emerging economy and part of the second-generation cluster of emerging economies (CIVETS[25]) following the "BRIC" countries. This momentum of economic growth continues to animate urbanization[26], creating opportunities for building competitiveness but also posing major challenges for the preservation of well-being and environmental quality in cities. In spite of Bogota's recent positive transformation and its growing status as a model of sustainable urban development in the region[27], a number of urban environmental quality indicators in critical areas still fail to meet the minimum local and international standards related to air quality, climate change, vegetation per capita, noise, storm water management, biodiversity loss, and depletion of natural capital.

Air pollutants have been significantly reduced[28] in the city after the implementation of several measures and programs: annual vehicle engine check ups on an individual basis, restriction on the daily quantity of vehicles allowed to circulate, and enforcement of regulations for

FIGURE 2. IMPLEMENTATION OF VEGETATED ARCHITECTURE IN BOGOTÁ. RECIVE, 2014

industry emissions. In spite of this progress, particulate matter concentration in Bogota is still one of the highest in Latin America[29], particularly in critical areas[30]. National and local regulations are enforced to control noise emission. Nevertheless, noise levels up to 85dB have been reported[31] in several problematic zones[32] (mainly produced by traffic, industries, bars and aircraft operations).

Buildings and impervious ground surfaces occupy 67% of Bogota's urban area. The increase of inert surfaces and the resulting reduction of green surface have contributed to the formation of two urban heat island areas[33]. A local study determined that the temperature in Bogota rises 0.2 degrees Celsius per decade. It is estimated that by 2050, the average temperature in Bogotá will be 2 to 3 degrees higher compared to the present[34]. Construction activity also has a significant impact on the amount of waste[35] produced in the city and the reduction of natural habitat[36].

The Territory Organization Plan (POT)[37] is the main long-term planning instrument to counteract the environmental degradation pressure posed by urban economic grow and rural exodus. First decreed in the year 2000 and recently amended, it was conceived as an urban development model that establishes the city's development goals as well as the governance strategies and management actions for its realization. A key governance principle of POT is the provision of environmental services because it not only embraces the social, environmental and economic goals, but is also directly related to management of the three key physical structures of the city 1) the main ecological structure, 2) the functional structure of services, and 3) the spatial and socio-economic structure. The POT advocates for urban operations that integrate these three structures, but such interventions usually require available land, which is a limited resource in the city[38]. Biotectonics stand as a solution of high value, because it is a synergistic way of creating multiple urban environmental services while integrating the elements that comprise the physical structure of the city, without compromising land that has been prioritized to meet the low-cost housing demand[39].

The last version of Bogota's POT maintained the triple structure management scheme to target strategic development goals: Increase environmental quality and resilience via balanced distribution of environmental services throughout the metropolitan area, foster competitiveness via development of multifunctional centralities, and reinforce functionality via full coverage of support networks (utilities, functional infrastructure, public space and transportation networks). The social underlying principles of these aspirations are equilibrated distribution of these physical structures and extension of their benefits to all communities.

2.1. Main ecological structure

The main ecological structure[40] of Bogotá is defined as the interconnected network of green belts and spaces with high environmental value, which support both biodiversity and the main ecological processes for creation of ecosystem and environmental services[41]: eco-

Green roof. Columbia. Source: A. Ibañez.

productivity[42]. It consists of eco-productive natural and man-made elements classified into natural areas protected, areas of important ecological functional value, and complementary connecting elements[43]. Vegetated pieces of infrastructure serve as key articulators in the ecological structure, making it possible to create living 3D corridors in highly urbanized areas lacking natural elements.

The integration of biotic tissues into the inert urban fabric results in a number of specific management actions related to the ecological structure: Increase of green surface area, prevention of floods, storm water control, mitigation of heat island effects, enhancement of local biodiversity, noise absorption, and improvement of air quality. To reinforce ecological functionality of the overall eco-productive network, biotectonics implemented in Bogota should include biotic components that create harmonic interfaces with the local ecosystem's key flora and fauna (wetlands, páramos, mountainous, xerophytic and savanna). For this purpose, the Biotic Roof Guidelines of the city created the type "*Ecologically specialized*[44]", which aims to promote the installation of biotectonics that replicate these local ecosystems. In cases with certain building restrictions, conventional biotic roof systems can be integrated with other bioengineering solutions on the ground[45] to maximize the eco-productive potential of the site and balance the environmental services in critical areas.

2.2. Socio-economic and spatial structure

A multi-centric spatial scheme supports Bogota's socio-economic urban development model[46]. The POT identifies 21 centers that concentrate economic activities, job offers and social services, creating functional platforms for fostering competitiveness and wellbeing. These "*Areas of Intensive Economic Activity*" are classified according to several aspects: extension of their influence, diversity of functions and services provided, affluence of floating population they attract, and how they relate to residential functions[47].

The "*Traditional City Center*" has a major strategic function due to the diversity of services it provides for all the metropolitan area, the large amount of floating population it attracts, and the land use mix it encompasses. "*High and Mid Impact Centers*" concentrate commerce and industry-related activities, which attract a great number of people daily but have little or no presence of housing. "*Commerce and Service Centers*" have housing but they mainly offer a diversity of social and business services, which attract population for employment, education, or other cultural services. "*Areas of Proximity*" are fundamentally residential areas and "*Areas of Integration*" are residential areas combined with localized economic activities. Vegetated infrastructure and biotectonics are a potential urban strategic operation[48] to address socio-economic needs and help attain the specific objectives of this spatial multi-centric and multi-scale structure via different typologies.

There are several strategic actions to be prioritized in residential areas. "Biotic Roof Gardens" and "Cultivated Biotic Roofs"[49] can serve as communal green spaces and amenities (enforced by the urban planning regulations) to promote the integration of communities. In "*Commerce and Service Centers*", biotectonics can contribute to increased productivity by enhancing building services related to indoor environmental quality (mainly acoustic and thermal isolation[50]) and green open space. In industrial centers distant from residential areas, "Self-regulated Biotic Roof Gardens" are an economic source of environmental services for the whole metropolitan area (water management and heat island effect mitigation) and a mechanism to mitigate impacts of industrial activity on the immediate surroundings (noise isolation and capture of particulate matter).

Finally, in the areas with the most functional diversity and varied mix of uses including housing, diverse biotectonic systems provide specific solutions to address site-specific needs. However, to avoid disturbance of residents, emphasis should be placed on implementations that provide intensive mitigation of negative environmental impacts generated by economic activity (concentration of GHG[51], noise absorption, capture of particulate matter).

2.3. Structure of functions and services

This structure is comprised of general public utility systems, mobility infrastructure, public space, and public facilities[52]. The aim of POT here is to ensure that these elements are available in all areas of the urban territory to support the operation and development of the socio-economic and spatial structures. In addition to the main localized sources of services (water treatment plants, main transportation system nodes, etc.), decentralizing operations (such as biotectonics) are necessary to provide full functional coverage throughout the metropolitan territory.

Dispersed interventions with vegetated infrastructure can be considered part of the city's water management, because they operate as punctual engineered systems that attenuate the storm water peak flow, reducing runoff and eventually removing pollutants. This is a key function in peripheral areas without full coverage, flood risk areas, and dense areas lacking natural ground surfaces that allow storm water infiltration.

One of the main POT's strategies is to counteract urban sprawl by increasing density in existing areas. This agglomeration results in a high demand of parking spaces in the centers of intense economic activity. Underground parking facilities offer a double solution for this new urban scheme, simultaneously creating spaces to meet the demand and ground-level decks to be covered with "Biotic Roof Gardens", which increase the area of green space as a public amenity. Transportation infrastructure and public buildings also serve as dispersed platforms to produce additional environmental services through biotectonics. A project to install self-regulated biotic roofs on the stations of the city's massive bus transportation system – Transmilenio- is currently on going[53].

The latest POT has introduced several programs and governance instruments involving public entities to promote biotectonics. The Secretary of Planning, the Secretary of Habitat and the Secretary of Environment are currently collaborating to develop a scheme of incentives for sustainable construction in the city. This scheme entails a number of building measures for climate change adaptation: storm water management systems (harvesting, evaporation for microclimate control and runoff alleviation), biotectonics and other forms of vegetated infrastructure, urban agriculture, and renewable energy technologies[54]. In rural peripheral areas, projects having biotic roofs are allowed to increase their building footprint index by 0.05[55].

3. BIOTIC ROOF GUIDELINES FOR ECO-CITY STEWARDSHIP

The main catalyzer of these multi-actor initiatives is the official Biotic Roof Technical Guidelines of the city (BRG)[56]. It was formulated to encompass a diversity of technologies, embrace the diverse group of local stakeholders involved in the application of the practice, and target the city planning goals. To meet this triple purpose, the BRG adopted a novel approach, alternative to most of the existing vegetated infrastructure guidelines worldwide.

A number of guidelines, manuals and policies worldwide[57] provided technical reference for the BRG; however, an *ad hoc* approach was adopted after engaging different stakeholder actors in the elaboration process. During the socialization, it became clear that the guidelines should provide an inclusive technical baseline giving room to a wide range of vegetated infrastructure technologies (also low-cost local adaptations[58]), and in addition, provide clear information on how the technology functions. These two requisites suggested that the guidelines shouldn't be based on fixed prescription of materials and components but in the performance associated to operation of the technology in different scales (from the components to the city scale). As a result, the BRG incorporated its own distinctive structure and contents: 1) New definitions and classification, 2) Function-based structure, and 3) Multi-scale life-cycle approach (Figure 3).

3.1. Components

A biotic roof system is comprised of three types of components, regardless of the technology used: 1) Active components, 2) Stable components, and 3) Auxiliary elements. The success of a biotic roof depends on achieving proper interactions and interfaces among these types of components and on how they are adapted to a specific piece of infrastructure.

Active components are expected to present constant physical-chemical changes for sustained operation throughout the lifecycle of the biotic roof. These components are the biological elements or elements that support lie in the system: vegetation and growing media. Their sustainability depends on their physical interaction and their capacity to adapt to changing environmental conditions.

Stable components are the inert elements of the systems that must maintain physical-chemical stability to operate properly throughout the lifecycle of the biotic roof. They are manufactured elements that are designed to perform specific functions in the system (waterproof membranes, root barriers, filtration mats, draining sheets, etc.). The durability of these components depends on their capacity to resist environmental conditions, humidity and

Green roof. Columbia. Source: A. Ibañez.

organic agents (such microorganisms and fungi).

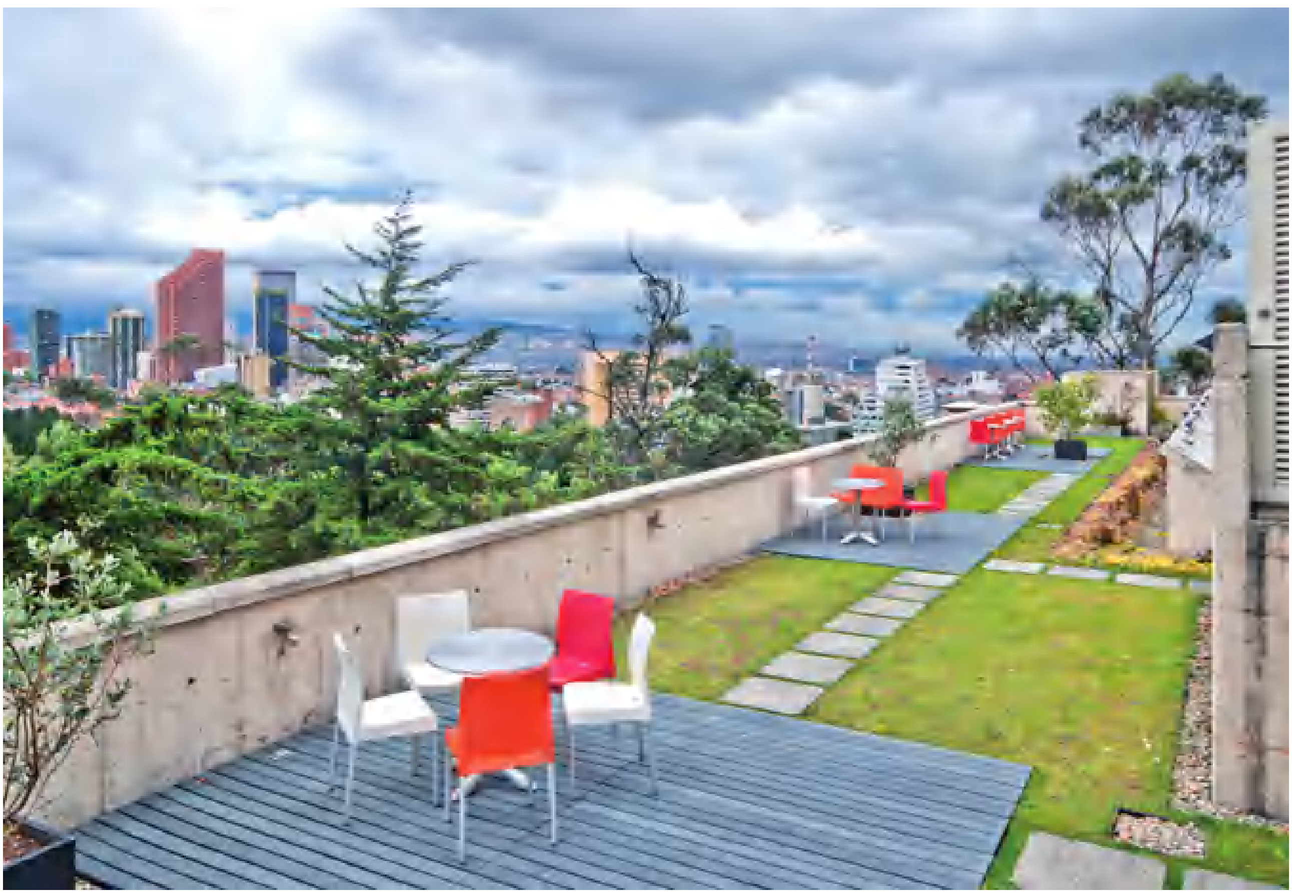
Auxiliary elements are additional stable components needed to place and fix a typical biotic roof system section onto a building or piece of infrastructure. They perform several functions related to installation or maintenance: Separation, confining, protection, water evacuation, irrigation, lighting, etc.

3.2. Multi-scale approach

The BRG sets the technical and operational aspects of biotic roofs associated with benefits obtained in four scales (Fig. 3):

- Scale 1: The biotic roof system used (typical section of a biotic roof).
- Scale 2: The specific adaptation of the biotic roof system on a piece of infrastructure (overall biotic roof).
- Scale 3: The functional and structural integrity of the building intervened with the biotic roof system (the overall piece of infrastructure).
- Scale 4: The integration of the biotic roof system into the ecological structure of the city (the specific urban area where the biotic roof is located).

The substantial advantage of biotic roofs in comparison to conventional surface systems is the overall added value resulting from a number of distinct functions obtained. While other building surface systems are aimed to



Green roof. Columbia. Source: A. Ibañez.

provide a single or tandem function, i.e. solar reflectance or thermal remittance[59], biotic systems are known to perform various environmental and technical functions simultaneously, creating multiple benefits. The BRG identifies the key functions for each scale of performance, and sets the minimum requirements and recommendations to achieve these functions regardless of the technology used[60].

In addition to the basic functions of mandatory compliance, the BRC also establishes advanced and special functions (of voluntary application) for eligibility to future incentive schemes:

Basic functions (mandatory)

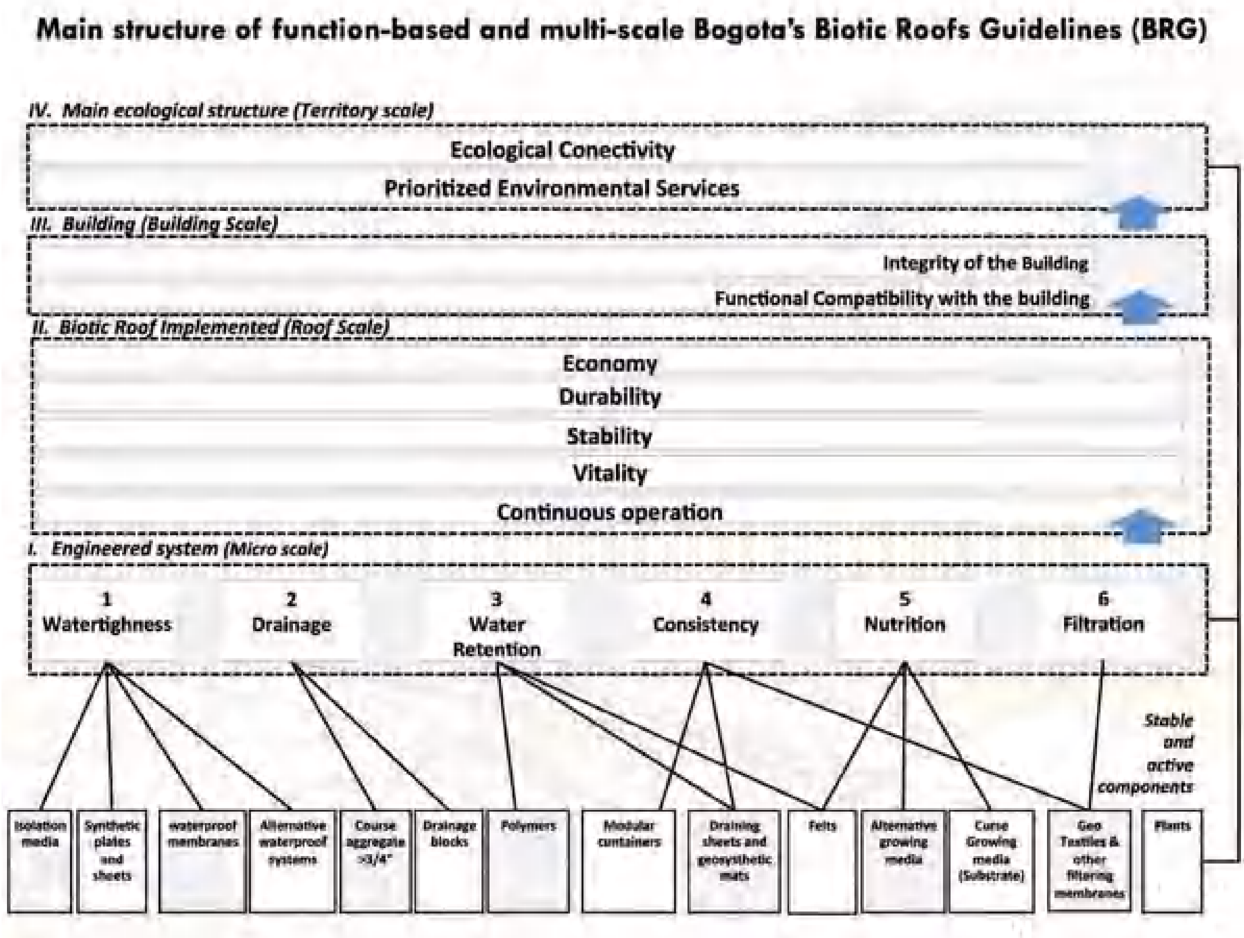
- Scale 1: waterproofing, drainage, water retention, mechanical stability, nutrition and filtration.

- Scale 2: Sustained operation, biological stability and vitality, mechanical resistance and stability, durability, and economy.

- Scale 3: Functional compatibility, physical integrity.

- Scale 4: Ecological connectivity and provision of priority environmental services.

FIGURE 3. MAIN STRUCTURE OF BOGOTA'S BIOTIC ROOF GUIDELINES



Advanced functions (recommended)

• Lightness

• Self-regulation and low maintenance

• Thermal isolation

• Acoustic isolation

Special functions (for future incentive schemes)

• Evapotranspiration

• Reduction of storm water runoff

• Reduction of peak flow and total volume discharge

• Capture of CO_2 and other GHG

• Emission of oxygen

• Ecological restoration and biodiversity

3.3. Flexible contents

For each function in the four scales, the BRG elaborates on the following sections:

• Purpose: describes the biotic roof's expected performance associated with a specific function.

• Key aspects: highlights the general design and technical aspects that are decisive to achieve the specific function.

A living wall in Columbia. Source: A. Ibañez.

• Requirements: refers to the mandatory practices that should be ensured at all times to achieve the desired performance (regardless of the technology used).

• Properties and units associated: identifies the properties and units to be considered for detailed design, calculation, or planning of biotic roofs in relation to the function addressed.

• Recommendations: describes the best well-known practices associated with the technologies most widely utilized (multi-layered systems).

4. CONCLUSIONS. TOWARD A NEW ECO-URBAN

As the urbanization frenzy continues to cause decay of the natural eco-productive systems and pose serious implications for wellbeing, the expectations over a new development paradigm push human aspirations beyond the so-called "sustainable" approach. At the core of the emerging positive development proposition, not only are human actions able to minimize the loads on the environment but produce positive environmental and social impacts. The success of this higher aspiration depends to a great extent on how urban settings can adapt to present challenges, particularly in existing “developing” cities that face the two-fold scenario of attaining what has been omitted in the past and implementing up-to-date measures to meet future global needs.

This implies a reformulation of the way cities have been planned and managed. In addition to major strategic urban operations, existing cities demand tactics that allow incremental positive change to happen. For this transformation to happen in the complex and dynamic urban realities, it is necessary to shift the perspective from management toward stewardship, which allows room for multiple actors to engage in the transformation of habitat *co-evolutionary*. The process of implementing biotectonics in Bogota has shown how small and dispersed interventions on the built urban fabric may result in a progressive transformation of the overall metropolitan area, *multi-scale*, and how inclusive guidelines may help to promote solutions that address different problems simultaneously, *multi-functional*.

With the proliferation of local experiences in development and implementation of eco-productive technologies for the built environment, cities around the world are likely to reformulate planning and stewardship instruments to meet the needs of the new eco-urban.

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NOTES

[1] Latin America is the most urban mega region of the world, with four-fifths of its population lives in cities. By 2050, 90% of Latin America's population is expected to live in urban areas. United Nations Human Settlements Programme (UN-Habitat).

[2] The term *biotectonics* is introduced to differentiate building greening (biotic roofs and biotic walls) from other forms of green infrastructure. From bio (*living*) and tectonicus (*building*).

[3] *Positive* is a term recently introduced as subsequent and complimentary to the concept of sustainable development. Applied to construction field it is defined as human development that "leaves ecological and social conditions better off after construction than before". In a broader sense, *positive development* "would actually expand the ecological base, meaning ecosystem goods and services, natural capital, biodiversity and habitats, ecological health and resilience, and bio-security". See BIRKELAND (2008).

[4] Between 2008 and 2013, academic and mass media sources had published 50 publications about local Vegetated Architecture developments, some retrieved from http://biotectonica.com/en/?page_id=253 and http://biotectonica.com/en/?page_id=237. January 10, 2014.

[5] See: Ibañez, R.A., Cárdenas, M. (2012), p. 10 (Spanish).

[6] Other fields: construction, ecology, biology, engineering and urbanism.

[7] Term introduced by architect Kenneth Frampton to highlight the constructional craft nature of buildings.

[8] Ibañez, R.A. (2008) and Ibañez, R.A. (2009). See also: *Matices* No. 20, National University of Colombia, retrieved January 16 from http://historico.agenciadenoticias.unal.edu.co/matices/and http://www.agenciadenoticias.unal.edu.co/detalle/article/techos-verdes-capturan-co2-de-bogota/

[9] *Also green roof*. The Technical Biotic Roofs Guidelines of Bogota advocated for the use of the term *biotic* instead of *green* to refer to the living condition of this type of technology.

[10] Technical parameters were determined and tested for draining components, substrate, plants and complete systems exposed to local environmental conditions during one year. Weather factors monitored: Rain volume, air temperature, heat index, humidity and wind. See also: http://www.greenroofs.com/content/Pioneering-Vegetated-Architecture-in-Colombia.htm retrieved January 18, 2014.

[11] Medellin, Cali, Santa Marta. See: Lopez (2010), Arias(2010), and ZielinskiI et al. (2010).

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[13] Applications of Biotic Roofs as sustainable urban drainage system. See: León E. (2010).

[14] Research-oriented entrepreneurship project selected as finalist in the award Innovators of America, 2011: Biotectónica, Andrés Ibáñez Gutiérrez. Retrieved January 16, 2014 from: http://inspiracion.innovadoresdeamerica.org/icms/en/2013/finalists/7321/ricardo-andrés-ibáñez-gutiérrez.do, see also: http://m.youtube.com/watch?v=80Z2HC__st4

[15] For definition of *Self-regulated Biotic Roof* see: Ibañez, R.A., Cárdenas, M., (2012), p. 14-19. For description of the biotic roof installed see: http://www.eltiempo.com/archivo/documento/CMS-5694309, retrieved January 14, 2014 (Spanish).

[16] The average area of biotectonics implemented per year in Colombia since 2009 was estimated in 12.796 square meters. 82% of the potential market is concentrated in 5 strategic zones: Capital region, Paisa Region, Santander, Costal region, and Valle del Cauca. Bogotá accounts for one quarter of the overall market available in the country. See Ibañez, R.A. (2012), p. 3 (Spanish).

[17] Out of a 48-projects sample and 12 building

programs considered. The largest single project located in Cartagena incorporated approximately 7.000 square meters of Biotic Roofs, See: Ibañez, R.A. (2012), p. 3 (Spanish).

18 See abstract: "*Bioroofs: Interfacing nature and building systems in Colombia. An integrative architectural design approach*", lecture at the World Green Infrastructure Congress, Hainan, China, 2011, R. Andrés Ibáñez. Retrieved January 16, 2014, from http://recive.org/eventos-y-noticias/ (English).

19 See: http://biotectonica.com/en/?page_id=210, retrieved January 18, 2014.

20 Red Colombiana de Infraestructura Vegetada, member of the World Green Infrastructure Network, WGIN. See: www.recive.org (English and Spanish). News retrieved January 18, 2014 from http://www.humboldt.org.co/iavh/component/k2/item/301-colombia-ya-cuenta-con-la-primera-red-de-infraestructura-para-techos-verdes (Spanish). Founding Members: Biotectonica, Groncol, Arquitectura Más Verde and Ecotelhado Colombia.

21 1) Technical and Scientific, 2) Financial Sustainability, 3) Communications and promotion, 4) Advisory and education , and 5) Regulations. Retrieved January 18 from http://recive.org/lineas-de-accion/

22 Bogotá City Council, Secretary of Planning, Colciencias and Secretary of Environment. See: http://ambientebogota.gov.co/web/una-piel-natural-para-bogota/inicio, retrieved January 18, 2014.

23 Since 2010, founding members of RECIVE have participated in the annual World Green Infrastructure Congress and other National conferences: Mexico City, 2010; Hainan, 2011; Nantes, 2013; San Francisco, 2013; and Singapore, 2013. See: http://recive.org/eventos-y-noticias/, Retrieved January 16, 2014 (English). RECIVE is part of the Latin American Green Infrastructure Network (LAGIN), with other members from Argentina, Bolivia, Brazil, Chile, Cuba, Mexico, Peru, Puerto Rico y Uruguay.

24 Humboldt University, Berlin. See: Herfort, S., Tschuikowa, S., Ibañez, R.A. (2012 and 2013).

25 The CIVETS countries are Colombia, Indonesia, Vietnam, Egypt, Turkey and South Africa. Economist Intelligence Unit, 2009.

26 Today, there are 71 cities with more than 100.000 inhabitants and 7 metropolises with more than 1 million. Since 1940's, Colombia's urban population has increased from one-third to three-quarters of the country's total.

27 See: Latin American Green City Index. Retrieved January 16, 2014 from http://www.siemens.com/entry/cc/en/greencityindex.htm?section=index/nav/gci_southamerica

28 The annual average concentration of SO_2 in the air was reduced from 16,7 ppb in 1999 to only 2,7 ppb in 2012. NO_2 presented the highest annual average concentration values in 2009 to reach the international maximum cutoff point of 21.3 ppb, but it was reduced to 15.5 ppb in 2012. See: Observatorio Ambiental de Bogota D.C., retrieved January 6, 2014 from http://oab.ambientebogota.gov.co

29 After Mexico D.F. and Santiago de Chile. Ibañez, R.A. (2009).

30 The areas in Bogota with the highest concentration of particulate matter are Puente Aranda, Kennedy, Fontibón and El Tunal, with values above 100 $\mu g/m^3$. These readings are associated with mortality of 100 infants per year, and known as cause of respiratory problems affecting 31.000 children up to 5 years old. Ibañez, R.A. (2009).

31 In the first semester of the year, more than a thousand complains were raised. 12,8 of operations in the airport showed noise levels above the permissible value range. More than 3000 sources of noise pollution have been identified in the critical areas. Ibañez, R.A. (2009).

32 Traditional city center, Puente Aranda, Engativá, Fontibón, Santa Fé, Kennedy and areas in the proximity of the airport.

33 In Bogotá there are 0.15 trees per capita. International standards establish a desirable ratio of 0.33. The surface of green areas per capita recommended by United Nations is 10

m^2. In spite of the progress achieved in recent years by the local urban planning regulations (POT), in Bogota this value is estimated in 4.2 m^2.

[34] See: Pabón D.J. (1998).

[35] It is estimated that 200.000 tons of construction waste are discarded in landfills per year, and additional 473 tons in public spaces, in spite of prohibition by law. Ibañez, R.A. (2009).

[36] More than 90% of the urbanized areas have null or very limited potential for biodiversity. 28 species of wild birds are considered in risk of extinction. SECRETARY OF ENVIRONMENT, (2008).

[37] See: Alcaldía Mayor de Bogotá D.C. (2013).

[38] Bogota metropolitan area has 1.647 hectares of available land, compared to 4.624 required for the next decade. Catastro Distrital, 2012.

[39] See: Alcaldía Mayor de Bogotá D.C. (2013), p. 437.

[40] See: Alcaldía Mayor de Bogotá D.C. (2013), p. 55.

[41] Ecosystem services are defined as the "benefits people obtain from ecosystems". These services are classified into provisioning services, which in general include materials and energy; regulating services such climate regulation and air purification; cultural services related to intangible human needs such recreation; and supporting services which are necessary for all other services such photosynthesis, soil formation and nutrient cycling. See: WRI, (2005).

[42] Term introduced by this publication to refer to the space-ralated capability of producing and delivering environmental services, applicable to land, natural elements or infrastructure.

[43] *Natural areas protected*: mountains, Bogotá River and rural land. Areas of important ecological functional value: wetlands, water bodies and their surroundings, riverbeds, non-protected páramos. Complementary connecting elements: parks, ecological connectors, channels, and vegetated infrastructure.

[44] See: Ibañez, R.A., Cárdenas, M., (2012), p. 16 (Spanish).

[45] e.g., living machines, bioswales, and other technologies that allow water infiltration.

[46] See: Alcaldía Mayor de Bogotá D.C. (2013), p. 240.

[47] This scheme is comprised of 3 types of urban areas: Areas of Intensive economic activity, areas of integration, and areas of proximity. See: Alcaldía Mayor de Bogotá D.C. (2013), p. 240-247.

[48] A strategic operation should be intended to simultaneously address the objectives of the three main urban structures. This can be achieved with biotectonics as shown in this publication. See: Alcaldía Mayor de Bogotá D.C. (2013), p. 244.

[49] See: Ibañez, R.A., Cárdenas, M., (2012), p. 15 (Spanish).

[50] Several office buildings and hotels located near the airport have incorporated biotectonics as a noise isolation mechanism, e.g., Aloft hotel, designed by Biotectonica. See: http://col.sika.com/es/group/News/Cubiertas-Verdes-Hotel-Aloft.html, retrieved January 16, 2014.

[51] Herfort, S., Tschuikowa, S., Ibañez, R.A. (2012 and 2013).

[52] See: Alcaldía Mayor de Bogotá D.C. (2013), p. 339.

[53] Bylaw 219, 2012, Bogotá City Council. Retrieved Jan 19 from http://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=48937

[54] See: Alcaldía Mayor de Bogotá D.C. (2013), p. 140.

[55] See: Alcaldía Mayor de Bogotá D.C. (2013), p. 366.

[56] Ibañez, R.A., Cárdenas, M., (2012)

[57] See: Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (2002).

[58] Using recycled materials, postconsumer products and conventional low cost construction components such roofing panels. See: Ibañez, R.A. (2009).

[59] e.g., Cool roofs.

[60] The BRG classifies biotic roof systems into five types according to the technology used: 1) Monolithic multi-layered systems, 2) Elevated multi-layered systems, 3) Receptacle systems, 4) Mono-layer systems and 5) Aeroponic system.

The Khoo Teck Puat Hospital offers lot of niches for the patients. Source: M. Köhler.

ARCHITECTURE AND TECHNICAL SCENARIOS

Attended by hundreds of thousands of visitors each year, ArtPrize 2013 included a living entry, the "Back to Eden" greenwall, which unites the bonds between art, architecture and nature. Source: Greenroofs.com; Photo Courtesy of LiveWall. landscape, health, green urban markets. Source: L. Velazquez.

CHAPTER 12

EVOLUTION OF GREENING BUILDING TECHNOLOGY FROM GREEN ROOFS TO A GREEN INFRASTRUCTURE TOOL

Manfred Köhler
President WGIN

ABSTRACT

Vegetation on buildings offers many benefits to enhance urban environmental qualities. This book mainly prepared by WGIN members, will present state of the art of solutions about greening on roofs, facades and indoors, not only for aesthetic reasons but also as instruments of green infrastructure (GI). There is now so much knowledge to make buildings a little bit "healthier" by using vegetation, that it is the time to push these strategies to all cities, not only those in Europe. Such greenery is credited a good system in the green building certification systems. Green infrastructure can offer multiple benefits, known as ecosystem services (ES). This means the combination of a vegetation layer with technical structures on buildings is one solution for a healthier urban environment. Today, single examples exist nearly from all climate regions of the world to model how these strategies work.

This overview article summarizes some key effects of such green technologies in terms of their main benefits, like energy savings, rain water management, biodiversity enhancement and improvement of environmental quality for citizens. There are more than 1400 related academic publications (see: science direct survey of "green roofs", date: October 2013) available to give detailed numbers about these effects from various regions. There will be many more in future data banks. Although this is a comfortable data set, more detailed academic works are needed and welcomed in the future to close remaining academic gaps. Within and outside the WGIN network, researchers in about 30 countries are working on such questions. Finally all these results can help decision makers and politicians to set up individual strategies for their local urban market in the future.

KEY WORDS

Technology, evolution, green infrastructure.

1. SHORT HISTORY OF GREEN ROOF TECHNOLOGY

Green roofs are an ancient technology. The beginning can be dated from the Egypt pyramids

Roof gardening. Source: M. Köhler.

in Saqqara, ancient hanging gardens of the Mid-East and also examples from Greece and Rome. The insulation work was done with asphalt, reed, bricks and a layer of plump. There are also historic illustrations of wine bowed ships in the Antics (*Athen, Artist Exekias around 530 before Christ; in Ahrend*, 2007). Flat roofs had various uses for planters, decoration, edible plants and also protection against the sun. In antique times, green roofs were for luxury buildings; the technology to have heavy loads on the ceilings of buildings needed strong under-construction and was an architectural challenge. Since the beginning of 20th century, by using steel-concrete construction it has become easier and also fashionable by modern architects like LeCobusier and others (Ahrend, 2007).

Around the globe and in many cultures, smaller earth covered architecture was popular as an insulation and protection layer. In cold northern European climates from Iceland to Norway roof meadows insulated rural buildings well and kept the insides warm. In other countries from Germany to the Mediterranean, so called "ice cellars" were above ground buildings that helped to store ice blocks from frozen lakes until the summer time and acted as early types of refrigerators. Similar construction can be found in Mumbai as earth-cooled fresh water cisterns with a thick vegetation layer as protection against the heat.

Green covered buildings also have a long history of being military buildings to hide fortress and protect against cannon balls.

In garden history, the famous garden architect Peter Joseph Lenné used green roofs to integrate castle buildings into landscape parks about 200 years ago. The garden of the castle of Schwerin in North East Germany is an example of this, reconstructed as part of the international garden exhibition in 2007.

The number of roof gardens has increased with development in construction technology (Ahrend, 2007). In the beginning of the 20th

An indoor wall installation with water features in Hamburg. Green roofs. Source: M. Köhler.

century roof gardens were an eclectic urban fashion: it was a pleasure of the rich urban people in the modern cities to enjoy the nightscape banquets on roof gardens. There are examples from such ball-house structures in New York, Shanghai, Berlin and many other cities. For example, the young landscape artist Roberto Burle Marx from Brazil stayed with his mother in Berlin in 1929 and he not only enjoyed the wonderful greenhouse observatory of the Botanical Garden of Berlin, but also the Hermannplatz high rise with a state of the art roof garden on top of a department store. This inspiring stay was later the reason for many roof garden projects from his office, mostly in Latin America http://www.rogallery.com/Burle-Marx_Roberto/burle-marx-biography.html . Roof garden can be found around the world (Osmundson, 1979), but the type and style of insulation work were individualistic for a long time.

Also in the early 20th century, the first urban roof gardening examples were installed in many cities like Munich. Now nearly 100 years later, it is a new old trend to use roof spaces. Roofers developed at that time an "extensive" protection layer with gravel mainly to reduce the fire risk of tar roofs on simple rental barracks in the quick growing European cities.

The modern green roof movements started with environmentally engaged people bringing nature back to towns. There were several people all around the world in this development but one, the artist Friedensreich Hundertwasser, must be highlighted as one of the most important actors to bring awareness of green roof technology to a large audience.

The technical and administrative paper work on construction details were gratefully done by the FLL guideline group since the late 1970s. Prof. Liesecke was one of the most important names in these groups. Today there are many FLLguideline papers, such as the green roof issue in the (Lösken et al. 2008) edition. This guideline defines:

- Extensive: (synonyms Bio roofs, eco roofs), (around 10 cm of growing media, nearly no maintenance, no irrigation, dry adapted vegetation, mostly like *Sedum* and *Sedum* moss combinations.

- Semi-intensive: (growing media 10-20 cm, meadow type, ornamental plants, with irrigation system and regular maintenance)

- Intensive: (synonyms in other regions: roof garden, sky-gardens), growing media more than 20 cm, some areas up to 1 meter, suitable for all kinds of plantings, including shrubs, trees, and a lot of garden features like water ponds, pools and more.

By this definition urban roof farms are intensive green roofs. There are many variations possible, like "retention roofs", or water cleaning roof systems and much more. Under the FLL Standards, these are all included in these three types. Extensive green roofs can have undulated surfaces to optimize the microhabitats. In this case, this is an FLL form of an extensive or semi-intensive version. It must be ordered by the client as it needs more maintenance than the typical extensive roof with only one level of growing media.

Many other guidelines from FLL members for greening facades and indoor walls followed since that time. An overall comparable European FLL guideline is not yet finished. There is a discussion process in the USA; some details have to be prepared for each climate region separately. Several countries from the USA (ASTM 2009) to Singapore (CUGE 2013) now have guidelines for green roofs. In several countries like Columbia, groups are working on local adaptation (see: Ibanez, in this book). Green roof technology today is a secure way to establish plants on the top of buildings. While the basics will be the same around the globe, the differences are in the local plant selection and in different construction codes. The technology is simple, good and lasting as long as the buildings exist. There are a number of current

An industrial building in Lohne, Germany. Source: M. Köhler.

Extensive Green roofs also in the tropics. Source: M. Köhler.

generalized publications on green roof technology to see the variation in construction details for various climate zones (Köhler et al. 2012; Pfoser et al 2013, Weiler et Scholz-Barth, 2009, Tan, 2013). The connection between green in cities, green buildings, and the green infrastructure related to urban climate and possible climate change is extensively described by Koehler and Clement, (2013a, b) and Pauleit et al. (2013). The following chapter will summarize these benefits with a few basic numbers. The scientific list for green roofs is the longest, while the living wall technology is sufficient for several types of climbers and there are a number of researches working on living walls. To look at indoor greenery just as an element of green infrastructure is new. There are many publications to explain technical solutions, such as the consequence of using indoor greening as an air conditioning system, like the breathing wall technology that has been used since the mid-1980s from W. Amelung (http://genetronsystems.com) in Canada.

2. GREEN INFRASTRUCTURE RESEARCH

Definition:

The term GI used in this paper is focused on effects of vegetation in contact with, nearby, or in relation to buildings. Such plant-related effects are described as ecosystem services (ES) delivered by plants and vegetational structures.

2.1 Green roofs

Since ancient times, there was experimental work to realize roof gardens on difficult surfaces. Projects for the ancient emperors used the latest available technologies, like Archimedes' screws, to bring water on to the buildings. Also all questions on statics were challenging. Favorite roof plants in ancient times were agricultural plants, like grapes, olives and dates. The greening of the roofs, sometimes only in big pots and sometimes as layers, were connected in many times with the greenery of the facades.

At the End of the 19th century several roofers and architects experimented with green roofs as protection layer. For example, Rüber (1860) used a special type of tar to protect the construction from water penetrating through the roof layer.

After World War II a lot of chemical products made it easier to protect buildings against water penetration. PVC, or modified Bitumen products and also rubber layers were used as protection layers.

Also, experiments with several growing media and plant species helped to bring the technologies forward.

Environmental research in Germany focused first (Bornkamm 1961) on the plant species living on longer-existing green roofs.

Since the 1970s environmental questions became the focus of research. Today there are hundreds of results from various climatic regions that present the general benefits. Table 1 presents some of these results.

Benefits of green roofs: Key effects of green roofs as an instrument of green infrastructure

Green infrastructure is like a tool box with different chapters. Each tool has a range of effects depending on the selected methods and region.

The functions of GI are connected to the mass of the plant structures. The plants first offer shade to the building surface. The second effect is caused by the evapotranspiration function of the living plants, of the energetic processes of cooling by transforming sun radiation in latent and sensible heat. The third effect is connected with the plants themselves as they fix particles on the surface, including chemical materials used in plant growing cycles.

Lobby of a bank in Singapore. Source: M Köhler.

Roof garden, it is like an urban forest – around 20 years old in the City Center of Singapore. Source: M. Köhler.

TABLE 1. ECOLOGICAL VALUES - EFFECTS OF GREEN ROOFS – CRITERIA AND THE OVERALL RANGE OF EFFECTS

	EFFECTS	CRITERIA	RANGE OF EFFECTS	LINKS: SELECTED PUBLICATIONS
1	Energetic effects: winter	Selection of type and quantity of growing media Selection of type of vegetation	From a few up to 30% energy savings are possible depending on the type of construction.	Koehler et Malorny, 2009
2	Energetic effects: summer	Related to the evaporation rate, biomass and plant species	Effects of a few percent are possible, depending on the thickness of the growing layer and the further insulation in the construction underneath.	Tsang et Jim, 2011
3	Rain water retention	Selection of the right growing media, retention layer and plants	Depends on the type and thickness of the growing media. Arange, with a minimum of 11Liter/sq meter. A media depth of 10 cm has around 70% annual retention.	FLL, 2008
4	Species richness	Local species selection, number of microhabitats, size of roof, location of the roof, maintenance	Minimum: Moss-Sedum roofs. Better: multi-layered, highly diverse plantings. Many garden plants are possible if the maintenance is correct. It is not possible for many because, besides species, many variations and sub-species are possible.	Snodgrass et Snodgrass 2006, Dunnet et Kingsbury 2008
5	Biodiversity, pollination	Type of green roof material, intensity of maintenance work	Depends on the region. For example, in Europe up to 150-200 plant species are possible on extensive green roofs.	Ksiazek et al. 2012 Favorite tropical list, see Tan and Sia, 2005
6	Sound absorption	Efficiency depends on the type of growing media and plant density	About 5 dB(a) possible	Connelly, 2011, Renterghem et al. 2013.

TABLE 2. ENHANCEMENT OF THE EXISTING GREEN ROOF TECHNOLOGY (TODAY: TYPICALLY CALLED 1.0) AND FUTURE GREEN ROOFS WITH HIGHER FOCUS ON URBAN EFFICIENCY (CALLED GREEN ROOFS 2.0)

	TODAY: GREEN ROOF 1.0	FUTURE: GREEN ROOF 2.0
Relation between extensive and intensive green roofs	Relation today 85% to 15% in Germany	Shift to more intensive (roof garden structures) with a lot of variation in use
Vegetation layout	Today less "structure rich"	Richness in habitat structures; bio roofs
Biodiversity	Low	Rich: high structure and growing media
Irrigation	Extensive: no irrigation	Also extensive green roofs as systems to manage rain water Relation to urban water cycles
Insulation: effects on energy savings	Extensive green roofs have only a small effect on additional insulation.	Better values are possible using new criteria: -other growing media -greater thickness of growing media -higher biomass rate -more vegetation structures
Retention value of pathways on intensive roof gardens	In most cases, the pathways on roof garden are directly on the surface: this means no insulation value.	Retention layer under pathways on green roofs or filter materials to retain rain water
Quality management of green roofs	Today (including in Germany) no quality management exists. In many cases there is too little maintenance.	Development of a certification system to improve the green roof quality with criteria for plant cover, weed control and improvement of the main gutter systems every five years.
Green roof policy	In Germany today there are regulations in many building codes. In many other countries there are an upcoming number of regulations. Some communities are following, having incentive programs, in most cases 50% of the costs, and capped costs.	In the future: green roofs as parts of green infrastructure The incentives need to be related to the quantified functions offered by the construction.
Roof gardens, urban farming and urban roof gardening	Currently only very few food gardens.	Urban roofs or "food gardening" At the moment this is a new trend in many cities and more is possible in the next few years.
Maintenance	Extensive: low level at the moment. Intensive: depends on the structures; similar to gardens.	If there are aims to support native plants or a special amount of plants, specialized gardening work following ecological aspects has to be developed according to the goals of the projects.

2.2 Living wall technology

To cover walls and facades with climbers and plants is a technology as old as the green roof technique. Wine grapess are well known from ancient times. Quite new and with much more opportunities today are living wall systems (LW), also called vertical gardens (Koehler, 2008). This implements various solutions in construction details. For example, perfectly fixing to the walls to avoid heat flux between the LW and the other parts of a building skin is a must.

One of the main differences from green roofs is LWs are visible to all people passing on the street level. Connected with the LWs are many ecological aspects as described in the following table. Interesting for citizens is that such LWs offer a new view of normally groundcover plants. LWs make house facades unique. Beside ecological benefits, aspects of identification can be reasons to use such greenery (Pfoser et Jenner, 2013).

The effects of LWs are divided in two groups; the private benefits for the building owner, like insulation and climate regulation, and the public benefits at the streetscape or city levels (i.e.: fine particle fixation, noise reduction, and urban heat island reduction).

The number of suitable vines and other climbers including some cultivars varies between nearly one hundred in the colder climates of central Europe to up to more than 1000 species and cultivars in tropical climates (own survey, as example of a link for tropical climate: http://www.flowersofindia.net/catalog/vine.html).

In comparison to the climbers on walls, living wall technology (LW) has only been used for a few years. This new use of typical groundcover plants on walls and facades in boxes or trays uses soil as growing media or hydroponic systems. Technical solutions for this exist as patents from the mid-1930s up to today. (For example, see the U.S. patent of Stanley White, the wall bearing architectonic structure; Nr. 2113523). Though the general breakthrough took many years, Patric Blanck was the real pioneer of this idea, with the potential to spread such

Living walls on high-rise buildings. Source: M. Köhler.

Extensive green roofs exist since about 10 years in Lohne, Germany. Source: M Köhler.

projects out around the globe (http://www.murvegetalpatrickblanc.com/). Plantings without soil following his structure, of geo-felt layers, have been working now for about 25 years. These types of plantings inspire other inventors to develop further solutions for wall greening. This chapter shall give an overview about the state of the art growing technology. An estimated 60 different solutions exist, and more solutions are under development. Today this is a new movement in bringing nature back into cities.

For a few years there has been a step from single solutions to professional patented construction. Brand-independent tests of living wall systems (LW, see also Table 1 for definition) have been done in Singapore for tropical climates (Tan et al 2003), in Vienna since 2012 (Pitha et al. 2013) and in Neubrandenburg since 2010 (ongoing; for a preliminary publication, see Koehler et al. 2012). A survey in France has been done by Damas et al. 2013 as a comparison of about 250 new LW installations.

Damas (2013) presented an overview of completed projects in France. He investigated 250 LW installations completed in the past years. Roughly the same number of projects have been done by Patrick Blanc with his system around the globe. These 250 installations in France cover about 7000m² (as of the end of 2013). There is no number of existing LWs around the globe, but within the last year increasing tendencies are seen in all countries. One reason for increasing is that more people have access to such installations: they can see how the plants grow. This is helpful for the success and also financial incentive programs. For example, in Singapore there is a regulation that 50% or a maximum of 750 SinDollars will be reimbursed by the state (example 2013).

2.2.1 Typology of Living Walls (LW)

The following figure (Figure 1) categorizes different types of LW systems, following the systematic by Pfoser et al. 2013, and FLL 2014 with a huge number of different detail solutions.

TABLE 3. OVERVIEW OF CURRENT LW TERMS FROM SEVERAL LANGUAGES (E: ENGLISH, F: FRENCH, D: GERMAN, E: SPANISH; P: PORTUGUESE)

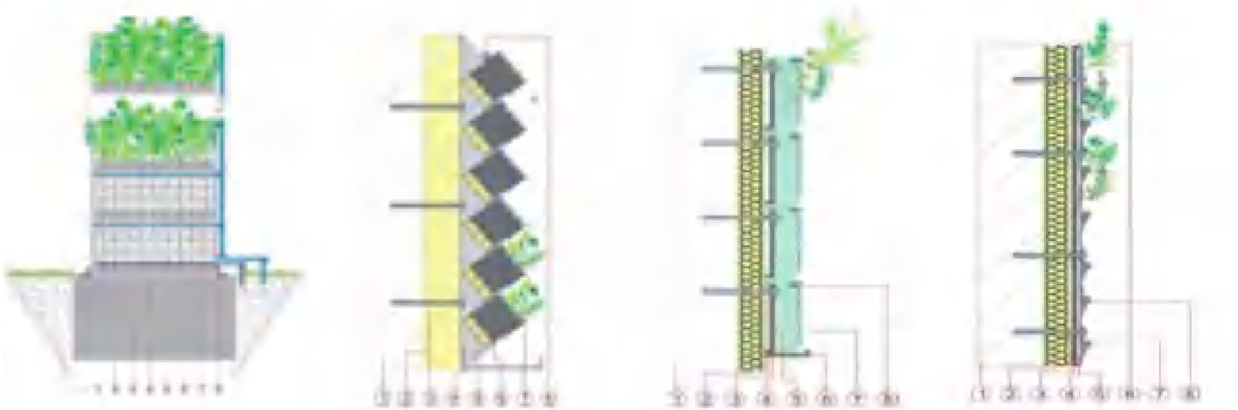
TERM	DESCRIPTION	CLIMBERS	NEW TYPES	EXPLANATION
Living wall, façades verde (E, B)	All types of facades, green walls	X	X	
Mur vegetal (F), Fassadengarten (D)	All types of fixing plants on vertical building structures		X	All types of plants are possible: maintenance is essential like in a garden
Bio walls (E)	All types of vegetation; focus of this type of greening on native plants to enhance biodiversity	X	X	Focus on native plants, vertical vegetation structures to enhance biodiversity in urban areas
Wandgebundene Begrünungssysteme (D)	All types of vegetation systems: this will be the new German technical term in the 2014 FLL guidelines.	X	X	Focus: in German “Wand” is more than only the “façade,” or the more decorative part of a building.

Additionally, a few deliverers are experimenting with “moss structures“ on porous stones. It will be exiting in the future to find long-lasting moss facades.

2.2.2 Research on LWs

Questions to be answered about LWs are regarding the initiating costs per square meter installation and the running/maintenance costs. A secure installation on the structural parts of the facades is obligatory. The life expectancy per system must be given. All these are technical questions, which shall be answered by the companies delivering the construction. LWs are garden elements that need frequent maintenance. Each system must define in separate in detail how long each part of the construction will last, what the regular exchange is and what normal

FIGURE 1. TYPES OF GREENING SYSTEMS AFTER KOEHLER ET AL 2012 (GERMAN: D, E: ENGLISH, AND F* FRENCH AFTER DAMAS, 2013)



Gabion style €
„Large metall cages“ (F)

Horizontal – small Small
Boxes (E)
Jadinères (F)
Modules preformes (F)

Vertikale Module (D)
Modules (E)
Metal cages (E) /cushins (E)
Cussins (F)
Cages metalliques (F)

Geovlies (D)
Geofelts (E) – Continuous
layer (E)
Sur nappe continuous (F)

maintenance work is. The overall construction should have a warranty of about 25 years (basic construction parts), while the irrigation system including the valves, dripper and hose connection has a lifespan of about 5years according to the material. Plants and growing media are dependent upon maintaining the construction a few times a year with exchanges and partly replanting.

Knowledge of such life spans must occur at the beginning. Questions about the complete system need certification. The surveys include tests of the construction materials.

TABLE 4. BASIC TOOLBOX ON ECOLOGICAL EFFECTS OF GREEN INFRASTRUCTURE, FOR EXAMPLE, LWS

	EFFECTS	CRITERIA	RANGE OF EFFECTS	LINKS: SELECTED PUBLICATIONS
1	Energetic effects: winter	-Selection of type (felt, media), size of the LW -Selection of plants and quantity of the phytomass -How the connection between the LW and the further façade is done is important.	Depending on the insulation of the wall, an effect of a few up to 25% additional insulation value	Ottele, 2011
2	Energetic effects: summer	Related to the evaporation rate, biomass and plant species	Infrared pictures demonstrate the surface temperature modified by LWs can be 5-10 degrees K. -Increases the relative humidity by 4-6% on a summer day	Mazzali et al. 2013 Perez et al. 2011.
3	Water need, evaporation capacity	Either the LW can be minimally irrigated only in order to survive, or they can be maximally irrigated to have high rates of evaporation	Depending on the storage capacity, the daily evaporation rate will be 1-3 Liter/m² felt on summer days.	Koehler et al. 2012
4	Binding on fine dust particles	Depends on the quantity of plant mass and plant surface structure	Well known results from climbers, few results from living walls; “significant fine particle sink”	e.g.: Sternberg et al. 2010.
5	Species richness	Many groups of plants are possible; climbers, shrubs, small trees, perennials, herbs and mosses. Further, these are vertical gardens.	Nearly all plants are possible if the garden work is well done. -The challenge is to also use local, native wildflowers for living walls.	Koehler et al. 2012.
6	Vertical farming	Size and number of planters	Quantity of the structures, from vertical boxes up to horizontal felt solutions. Food production has an additional effect on cooling and shading: various examples around the globe.	Sheweka et Mohamed, 2012
7	Biodiversity, pollination	LWs are thermophilic, synanthropic habitats.	Currently no fauna survey have been done on LWs.	No current survey exists
8	Sound absorption	Efficiency depends on the media; thick absorbing materials like foam-glass, stone wool are best for such effects. The influence of the plant species on this is smaller.	About 5 dB(a) are possible, similar to roof measurements.	Tan et al. 2009, Köhler et Milbrandt, 2012a

Now neighborhood with green infrastructure in Singapore – Changi City. Source: M. Köhler.

A living wall installation on the base of planter pots, Singapore. Source: M. Köhler.

TABLE 5. CHARACTERIZATION OF INDOOR GREENING ELEMENTS

	SIZE VARIATION	GROWING MEDIA
Planter boxes and ground-installed systems	From planter boxes to fixed planter beds	Hydroponic systems or mineral growing media, variation in organic content
Horizontal/ vertical systems	Horizontal boxes Façade covering, felt systems	Mineral media Hydroponic media Seamless felt solutions

2.3 Indoor greening

In temperate climates the preferred plant species for indoor greening are mostly the typical and easy-to-produce plants from subtropical and tropical regions. The German FLL guideline for indoor greening offers a recommended list of plant species, which are easy to get from horticultural gardeners. Such indoor plants must be easy to care for, not too aggressively growing and easy to handle. A list of 250 species are documented (Kerstjens, et al 2011). Many more plants are possible as nurseries offer more species. This is a real dynamic market with some fashion selection.

In subtropical and tropical climates it will be much easier to connect the outside vegetation with the indoor plantings to make a smoother connection between inside and outside. Here also vertical greeneries such as LWs will be a space-saving solution to bring vegetation with functions for climate regulation of buildings inside.

TABLE 6. TOOLBOX OF GREEN INFRASTRUCTURE: THE EXAMPLE OF INDOOR GREENERY

	EFFECTS	CRITERIA	RANGE OF EFFECTS	LINKS: SELECTED PUBLICATIONS
1	Energetic effects: summer, air conditioning function	Related to the evaporation rate of the system and to the biomass of the plant species;air humidification	Air purification dates, related to evapotranspiration.	Cheng et al. 2010 Koehler et al. 2012
2	Water need, evaporation capacity	Either the LW can be minimally irrigated in order to survive or they can be maximally irrigated to have high rates of evaporation.	Depending on the storage capacity, the daily evaporation rate will be 1-3 Liter/m² felt on summer days.	Koehler et al. 2012
3	Species richness	Many groups of plants are possible from various climate regions including temperate, Mediterranean and tropical climates.	Nearly all plants are possible if the garden work is well done. The challenge is to also use local, native wildflowers for living walls. Simplified species, (typically not massive growing tropical plants) with low light needs are on the basic list for plant selection.	Kerstjens, et al. 2011, Koehler et al. 2012. Min et al. 2006
6	Sound absorption	Possible effects		Measurements needed

Climbers are an opportunity to hide back yard facades. Source: M. Köhler.

3. THE FUTURE OF GREEN INFRASTRUCTURE TECHNOLOGY WITHIN GREEN BUILDING TECHNOLOGY

Following EU (2013), green infrastructure is a tool that offers ecosystem services (ES). The technical term ES describes the environmental benefits offered by vegetation in rural and urban areas (e.g. Hubacek u. Kronenberg, 2013). The earliest steps were to define the ES for rural areas with agriculture and forest habitats. Currently, such principles are also used for urban regions. The European community is going to address this at the level of policy and has developed several working papers about this issue (see EU 2012 in the list of references). ES can also be monetarily valued (Groot, et al. 2012).

The ES are strongly connected with the presence of vegetation. Trees and open land are known as climate regulators for the global water cycle. It has also taken a long time to develop a mutual understanding of the basics of the water cycle at a micro-scale level. Each tree and each square meter of vegetation is finally counted and from the small scale water cycle up to the generalized global scale (see: Kravcík, 2007 "Water paradigm"). Increasing deforestation and urbanization require many steps to repair and contribute to the struggle against climate change.

Today in nearly all countries from North America to Singapore, green roofs are built to reduce the massive impact of concrete cities and to bring healthier urban environments (Tan, 2013). It is easy to compare situations in cities with and without greenery. The presence of vegetation reduces surface temperatures. Pauleit et al. 2013 described this in an English city in terms of three levels of vegetation cover. The vegetation cover causes significant reductions in temperature. Decentralized vegetation on buildings is a way to support the small water cycle, which cools urban surfaces in summer and helps evaporate local water. The calculation of this effect is nearly easy. The well known amount of energy needed to transform rainwater into the gaseous form is roughly 2.250 (kJ/Liter water) depending on the water temperature (it can be a little less or more). This evaporation can be realized from bare soil or a pond surface, but is more highly effective through plants.

The typical 10 cm of growing media on *Sedum* roofs has an annual retention rate of about 75% of the local rain. In Berlin, this is about 450 Liter/m². In contrast, a gravel roof retains only about 10% or 50 Liter/m².

If the green roofs are a part of green infrastructure, that means more water will be captured in a cistern during heavy rain events. This can be good for the vegetation and for multiplying evaporation and local cooling rates, providing a chance for future green roof projects with more growing media and more dense vegetation.

Evapotranspiration is an energetic process. Vegetation should be re-implemented wherever possible. Vegetation quantity is the important factor to observe effects not only at a micro scale.

The million tree program of the UNESCO was a good strategy to increase the amount of vegetation. But where trees are not possible, green roofs, living walls and indoor greening systems can be developed as GI systems.

Green infrastructure performs the multiple functions of increasing ecological cooling rates and enhancing the quality of life for urban citizens, a social element. At the least, the reduction in cooling load also has an economic effect. This can be counted in the monthly running costs of buildings and means money savings for both owners and citizens. It will be perfect to see the upcoming EU programs on this. (EU, 2012a)

Green roofs as part of a "rainwater harvesting program" possible in nearly all climates

Tropical climbers to cover multi storey car Singapore. Source: M. Köhler.

TABLE 7. GI PROGRAM AND EVALUATION TABLE; ONE EXAMPLE

	TOOLS	SCALE	ALLOTMENT OF LAND USE	SIZE OF PROJECTS IN M²	EVALUATION CRITERIA
1	Extensive green roof: Rainwater retention	Level of building	Retrofit: inner city	1000m^2	Annual retention rate of local rain on property about 70%
	...				

• More soil moisture and better growing rates with more plant species

• More evaporation produces more clouds and more rain nearby

• Increased cooling load

• Depending on the number of such projects, a global cooling process is started with many benefits for all people of the neighborhood.

The building surface is one resource that could be used to install more vegetation. This vegetation structure can include trees, shrubs, herbs and some water features as well. It is now a question of creativity to turn green roofs into unique oases.

The technical term "green infrastructure" also used by the EU commissions includes the original elements of green roofs. The next step will be to construct green roofs as green infrastructure tools to deliver environmental benefits within and all around cities. The baseline is given in the following EU report: http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR3.pdf.This includes the optimistic core idea that higher density and enhancement quality of urban life are simultaneously possible. We can highlight Singapore as a city that is dealing with this connection well. At the same time that the population will exceed two million people, the idea of a "city in a garden" is the official planning term. This vision will only become a reality by using green infrastructure; vegetation on facades, roofs and the insides of buildings. This idea is not only possible in tropical climates but is a role model for all countries around the globe. The following results from various climate regions demonstrate the high potential of green roofs and green facades.

GI is partly a new concept in how to green cities wherever possible. The most important thing is to think in a systematic way. A single greened building can be a unique and beautiful solution. Each single step counts and the replication and systematic connection of this method can finally help against the risk of flooding.

A systematic overview of green infrastructure technology has been presented by Grant (2012). This is a new way of political thinking that hopefully will also be supported by the EU commissions.

As explained in this introduction paper, a lot of questions about the benefits of green infrastructure can be answered. Now is the time to bring this technology to all towns as a general solution. Now is the time to act at the level of each community.

The following table has a systematic overview that can be developed for each neighborhood and tailored exactly to each property. The instruments exist to count costs and get numbers about the benefits. This is a model for the calculation procedures needed in applying green infrastructure programs to cities.

Semi-extensive green roof in Berlin. Source: M. Köhler.

LINKS:

http://www.schweriner.de/index.php?id=56

http://www.neukoellner.net/zeitreisen/neukoellner-zeitreisen/

http://www.rogallery.com/Burle-Marx_Roberto/burle-marx-biography.html

EU 2012: Green infrastructure policy 2012: http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR3.pdf

Green infrastructure report:

http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR3.pdf

EU Environmental services: http://enrd.ec.europa.eu/themes/environment/environmental-services/en/environmental-services_en.cfm

EU, 2012a: The multifunctionality of Green infrastructure, http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR3.pdf

http://ec.europa.eu/environment/nature/ecosystems/studies.htm#implementation

EU 2013: Mitteilung der Kommission an das Europäische Parlament, den Rat, den Europäischen Wirtschafts- und Sozialausschuss der Regionen..Grüne Infrastruktur (GI) — Aufwertung des europäischen Naturkapitals. Brüssel, den 6.5.2013. COM(2013) 249 final

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CHAPTER 13
GREEN TOWNS AND ARS POETICA

Emilio Ambasz
Architect

ABSTRACT

This article proposes that Europe needs to complement its export-oriented economy with an urban consumer inner-directed economy. This can be better achieved, not by building roads that might bring the same disasters upon Europe they brought upon America, but, more imaginatively, by the creation of a large number of New Towns. Not only will they forestall migration to the larger cities but, more importantly, they will provide the European citizen with a sense of fulfillment-personal as well as social.

This article further proposes that such new towns should be Green Towns, ranging from 20-30,000 people. They should be designed taking into account both the possibilities that the electronic world offers us the ability to live far away from the traditional center of economic creation, as well as the certainty that human contact on a personal basis is a necessary ingredient for a wholesome life.

The author, an architect, will not expound here on the social, political, or economic reasons supporting his ideas but will, rather, discuss architectural and urban ideas, propose alternative models, and suggest ways wherein such new, Green Towns can be designed and developed to assure the economic well-being of the community, as well as the spiritual fulfillment of each individual living there. Examples will be drawn from the author's built work as well as on-going projects and proposed projects.

KEY WORDS:

New green towns, economic wellbeing, ars poetica, architecture design

1. BACKGROUND

There is a great tradition in urban planning, started in the late 19th century, towards creating garden cities. The most outstanding among many enlightened practitioners was Ebenezer Howard. He proposed the creation of garden cities which became the forerunners of those suburban communities which have developed around London. Later, similar minded movements introduced this idea to the United States where a number of such garden city communities were developed. Naturally, these

American communities were modified versions of the original British models, reflecting the larger availability of land as well as the beginning of an automobile-determined society. In essence, they were the forerunners of what we now know as the American suburbs. Since

ACROS FUKUOKA
FUKUOKA PREFECTURAL INTERNATIONAL HALL
FUKUOKA, JAPAN

The design for ACROS "Asian Crossroads Over the Sea" Fukuoka proposes a powerful new solution for a common urban problem: reconciling a developer's desire for profitable use of a site with the public's need for open green space. The plan for Fukuoka fulfills both needs in one structure by creating an innovative agro-urban model.

Among Emilio Ambasz' recent projects, ACROS Fukuoka - Prefectural International Hall is a most powerful synthesis of urban and park forms. Its north face presents an elegant urban facade with a formal entrance appropriate to a building on the most prestigious street in Fukuoka's financial district. The south side of the Hall extends an existing park through its series of terraced gardens that climb the full height of the building, culminating at a magnificent belvedere that offers a breath-taking view of the city's harbor. Underneath the park's fifteen one-story terraces lies over one million square feet of multipurpose space containing an exhibition hall, a museum, a 2000-seat proscenium theater, conference facilities, governmental and private offices, as well as several underground levels of parking and retail space.

The site, owned by the city, is the last large undeveloped plot in central Fukuoka. The city chose to develop the site in joint venture with private enterprise. In the scheme, a commercial developer will lease the land for sixty years and construct a building. A portion of the building's space will be devoted to public and municipal operations; the remaining allowable space will be revenue-producing. In deriving a proposal, the competing developers sought to maximize income potential. On the other hand, the architect was concerned about the effect of the development on adjacent Tenjin Central Park—the only green open-space in that part of the city. To the maximum extent possible, the architect wanted to give back to Fukuoka's citizens all the land the building would subtract from the city. Ambasz was awarded this commission for successfully achieving reconciliation between these two opposing desires: doubling the size of the park while providing the city of Fukuoka with a powerful symbolic structure at its center.

Along the edge of the park, the building steps up, floor-by-floor, in a stratification of low, landscaped terraces. Each terrace floor contains an array of gardens for meditation, relaxation, and escape from the congestion of the city, while the top terrace becomes a grand belvedere, providing an incomparable view of the bay of Fukuoka and the surrounding mountains. A stepped series of reflecting pools upon the terraces are connected by upwardly spraying jets of water, to create a ladder-like climbing waterfall to mask the ambient noise of the city beyond. These pools lie directly above the central glass atrium within the building, bringing diffused light to the interior through clerestory glazing separating the pools. Each year during the famous week-long Don Taku festival, the encircling balconies inside the atrium allow for a panoramic view as the procession passes through the building, while outside the stepped garden terraces become an inviting outdoor amphitheater for the entire city. A large "stone" like wedge at the foot of the terraced park pierces a V-shaped entrance into the building, revealing rough-hewn stone suggestive of geologic strata underlying the surface vegetation and likening the building to a massive block cut from the earth. This wedge shaped element also doubles as ventilation exhaust for the underground floors below and as a raised stage for performing artists.

The opposite side of the building faces onto the most important financial street of Fukuoka. Composed of striped glass, with every floor so angled as to reflect the passersby below, it softly de-materializes the mass of the building. The facade rakes outwardly from the vertical with each successively higher floor, creating the effect of an awning over the sidewalk. These overhanging eaves use the building design itself rather than an applied device to provide cover to pedestrians. The final stepped layers at the top create the effect of a large 45° cornice overhang at the street's edge, defining the public entrance while enhancing the building's urban presence.

This design has made the park and the building inseparable. The building gives back to the city the very land it would have taken away, and allows a major urban structure to exist symbiotically with the invaluable resource of open public space.

much has been written about them we will not dwell on them here.

Recently there has been a growing inquiry about the new American phenomena referred to as "Edge-Cities" wherein new suburban communities, having sprung fully grown on the edge of larger cities, are born fully empowered politically, capable as well as willing to contest the supremacy of the nearby large city. In all cases, suburbs and "Edge-Cities" are attempts at finding urban solutions that will be spiritually, as well as economically, fulfilling. To date we have evidence that none of the models built so far have satisfactorily succeeded. Moreover, we have great evidence that many of the new cities created from zero to become capitals, such as Brasilia and Ahmedabad, have been resounding failures. It is only man's infinite capacity for adaptation that lets them survive limping.

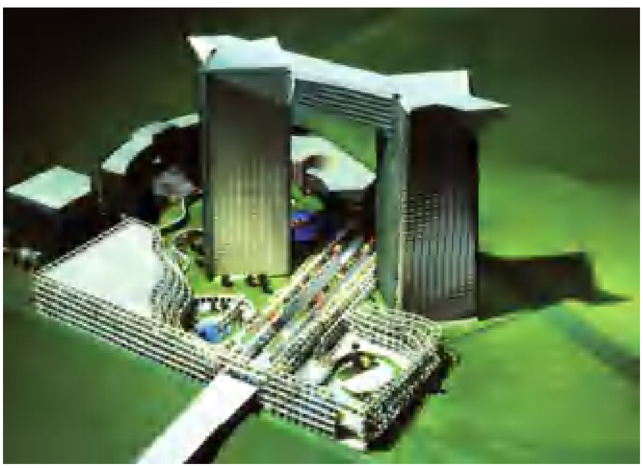
Therefore, there is a need to develop new models. This situation is especially critical in Europe where the present export-oriented economy has to develop a complementary inner-oriented economy which is designed to satisfy the needs and longing of its citizens. The present governmental initiatives for the investment in infrastructure as one way of achieving a pump-priming of the economy

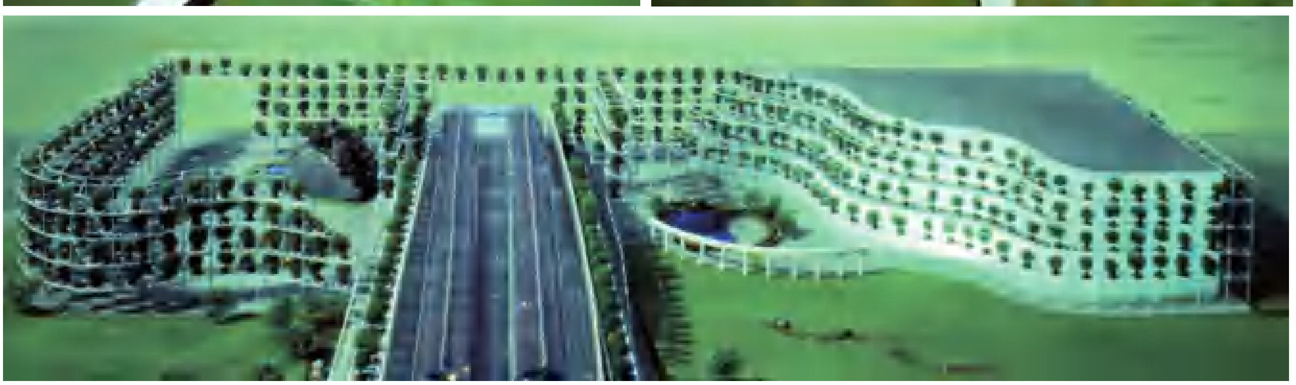
NISHIYACHIYO TOWN CENTER
NISHIYACHIYO, CHIBA PREFECTURE, JAPAN

With the advent of the high-speed rail system, distant agricultural areas of Japan have now been brought within easy commuting distance of Tokyo. Taking advantage of this new accessibility, one of Japan's leading investment corporations acquired a large area of rural property North of Tokyo to develop an entirely new suburban town, Nishiyachiyo, out of an agricultural area. While Ambasz was asked to design the new train station as well as the 24 acres of this new town's business center, consisting of a major department store, hotel, office space, museum, 3500 car parking, and recreation facilities, the surrounding residential areas will not be developed until much later. Ambasz was therefore faced with the immediate challenge of creating a commercial center that feels complete and welcoming even before the remainder of the town is built.

Visitors arriving at the new town would potentially be met by only empty flatness beyond the elevated train station, also designed by Ambasz. To give them a sense of arrival and enclosure, he developed a unique multi-tiered vertical garden to define and contain the boundary of the site, while providing a sense of presence for the city center. Designed as an open, ivy covered structural grid where each module contains a potted flowering tree, this vertical garden creates a natural, transparent transition between the new urban center and the open landscape beyond. To heighten the drama of the changing seasons, four different varieties of flowering plants will be uniformly used, each season bringing a new fragrance and color. Unlike traditional horizontal gardens, this vertical garden system not only allows its colorful patterns to be fully appreciated by visitors, but it uses minimal land for maximum effect in a country where land is a rare resource. It becomes a covered arcade at ground level, linking all of the buildings within the town center and softly integrating the existing train station with the new structures. This covered promenade defines two central arrival plazas on either side of the station, the North plaza with vehicle access for the train station, and the South plaza with pedestrian access for the public gardens and new commercial area. These plazas create a symbolic urban center for Nishiyachiyo, encircled by a covered shopping arcade which organizes all the buildings into one coherent and peaceful public space.

Towering above the complex, a huge Torii gate announces the city from afar to arriving trains which pass through it into the new elevated station. Composed of two 35 story office buildings connected by a lintel containing restaurants and a museum, the arrival gate is clad with a living green skin. This second skin, made of scaffolding hung with vegetation, veils the structure's glass curtain wall and visually connects the office towers to the gardens below. Formed by the scaffolding, continuous garden balconies rim each level and recall the roofed verandas of traditional Japanese houses. The vegetation-hung structure provides cost-effective passive climate control and anticipates new fire safety codes by serving as an alternate fire escape route. One side of each tower leans slightly as it rises, so that the gate seems to twist with an inner energy. Guided by Japanese architectural tradition, the arrival gate forms a dynamic symbol for this new city in search of an identity.





presents a magnificent opportunity for putting into practice a far richer and more satisfying procedure than just building a number of highways with all the concomitant risks that Europe may become as traffic blighted as any of the Western societies. No one in his right mind would wish to have a Los Angeles in Europe. This is not only because of the evils that a city, built around the car as a mode of transportation, brings about, but also because there is no longer a need to create large cities of over 200-500,000 inhabitants in order to create a center capable of self-sustaining economical production.

Today's electronic means makes it very possible for a very large number of professions to perform their tasks from home, or from satellite offices, without need of direct presence at headquarters. By the same token, it is no longer necessary for headquarters to be established in large cities in order to draw from its pool of talent, since now the pool of talent can be obtained nationwide. Such cases have proven to be true in areas of the economy such as insurance companies and banking. Even universities can broadcast their lectures and correct their students' papers via electronics. This author is far from fostering the notion that any social group can prosper without having direct physical contact. This would be an unwise foundation on which to build an idea, but it is also true that such physical contacts can be organized productively and designed to come about where needed, and not to be just the result of casual vicinity. We can certainly imagine someone working in a company four days a week from home, or from a satellite office in his own small home town, and going into headquarters only one day a week for special meetings with colleagues.

Moreover, in Europe there is an on-going process of decreasing the importance of the agricultural economy with the concomitant migrations to medium and large-size cities, and the depopulation of the rural areas. We have already seen what can happen in extreme cases such as, for example, in Mexico City, when the big city is understood to be one of the few economical resources available to the agricultural or provincial migrant. No society can operate with such unwieldy numbers.

Europe has in hand a great possibility of developing new towns. Such new towns should benefit from our understanding and experience gained from other such new towns created in Europe, and a few already created in Japan. Those new towns now emerging in China are too new to render reliable data. Ideally, such a new town should begin operation with a population ranging from 20-35,000 inhabitants. This will provide the critical mass necessary to support a number of social activities.

2. COMPONENTS OF A GREEN TOWN

Making new towns by repeating old suburban models, and worse still, repeating old mistakes, is not what is proposed here. What the author is proposing is that we create a new town which is a Green Town. We have had examples of suburban towns where the house sits in the center of the garden. We propose to go beyond the house IN the garden to have the "house AND the garden": one hundred percent of one and one hundred percent of the other. In some countries we have seen enlightened legislation aimed at having the "green surrounding the gray", that is to say, gardens surrounding the buildings. What is daringly proposed here is that we should have the "Green OVER the Gray". The author has spent the last 37 years of his professional life making proposals to create buildings which give back to the community as much of the green as possible. In some cases he has been able to give back 100% of the land in the form of gardens which occupy the same area as the ground which the building covers. (An example of this would be the Fukuoka Prefectural International Hall project.)

MARINE CITY WATERFRONT DEVELOPMENT
OTARU, HOKKAIDO ISLAND, JAPAN

Facing the windy Sea of Japan, Otaru shares the same climate as Vladivostok, Siberia. Built around an ideal natural port, this traditional Japanese town has a long history of prosperity. In recent years, however, Otaru has begun lagging in economic growth behind the other port towns on the island of Hokkaido. In reaction to this trend, the government of Otaru has formulated a vigorous plan to rebuild its industrial base and port facilities, improve community services, and provide for a large commercial development along the port to spur the growth of its emerging tourist industry.

A major competition was sponsored by the government for the commercial water front development. Because of the immense area requirements programmed for commercial use, most of the competing developers made proposals which covered every square foot of the waterfront, leaving no open public space. Ambasz, however, proposed a design which allowed over 60% of the new structures to be covered in earth and landscaped, providing an extensive urban park on the edge of the harbor. By linking gardens inside the structures with the natural landscape features of Otaru, this new park provides a sympathetic and inviting transition between the new built forms and their island setting. Although this proposal would yield less revenue than other development schemes, the government of Otaru awarded the project to Ambasz because his concept creates inviting outdoor public space in a city where such gathering spaces are very rare.

As the major organizing principle of his design, Ambasz links the existing railroad station with all the new commercial, residential, cultural, educational, and recreational facilities using a two-story serpentine, arcaded promenade. Canopied, arcaded shopping streets are a Japanese tradition. By transposing this concept onto the site in the form of a glazed promenade, Ambasz was able to offer protection from the harsh winters, while seamlessly uniting many diverse functions. Referred to as the "Maritime Promenade of the Four Seasons", this sinuous arcade offering constantly changing interior vistas is a colorful wintergarden allowing flowers and plants to exist year-round and anchored by an exhibition center/hotel tower at one end and a terraced apartment tower at the other. Near the water's edge is an open air boardwalk, like a symbolic reflection of the protected indoor arcade, moving outward to the sea.

The Maritime City Waterfront Development is one of the earliest examples of a technique Ambasz refers to as "the green over the grey," where architecture and landscape are blended into an organic whole to achieve a high density of profitable land use, while simultaneously providing extensive interior and exterior public park. And it is precisely this innovative extension of garden parkland which will make the Marine City Waterfront a civic and commercial success.

In other cases, such as in his recently completed building in the new town of Shin-Sanda (Mycal Cultural Center) the author has been able to give 80% of the land covered by the building back to the community. Moreover, the author was able to guide the client to an understanding that a building of this nature should be accessible to the whole community, used by the members of the community at large as well as by the corporation members who paid for it. The author's architectural formula of putting the "green over the gray," or the "soft over the hard," shows a very simple but profound way of creating new urban settlements which do not alienate the citizens from the vegetable kingdom, but rather, creates an architecture which is inextricably woven into the greenery; into nature as well as providing an excellent method for insulating the buildings against heat loss and /or gains.

The author would like the reader to understand that, as an architect, he feels very uncomfortable about not being able to show here, on account of space limitations, drawings and designs to better illustrate his ideas. Therefore, he begs your patience and invites you to follow a written description of just such an ideal Green town which is here schematically proposed. The author has worked on this idea, piece-by-piece, over the last 37 years. His method of work has been to create first a "catalogue," or typological sampling, of the different types of buildings which would be needed to house the diverse needs of such a new Green Town. These buildings have been designed according to the principles of the "green over the gray" and of giving back to the community as much as possible of the land covered by the building. Some of these buildings have been already built. Other buildings are being built in the United States as well as in Europe. There are also a few projects which have not yet come to fruition for reasons mainly having to do with the present economic recession.

Any Green Town to be created in Europe must be based on European cultural traditions as well as on its patterns of social and individual

LUCILLE HALSELL CONSERVATORY SAN ANTONIO, TEXAS

The Lucille Halsell Conservatory is a complex of greenhouses located in the hot, dry climate of southern Texas. Unlike northern climates, where traditionally glazed greenhouses maximize sunlight, the climate of San Antonio requires that plants be shielded from the sun.

This proposal uses the earth as a container and protector of the plants, controlling light and heat levels by limiting glazed areas to the roof. Since it is sheltered by earth berms, the conservatory preserves and harmonizes with the gently rolling hills around it. While the glazing is used as a cover for the earthen container, the roof is raised in places to accommodate tall plants. The varied forms of these peaks take advantage of prevailing conditions and orientation to the sun, and give the roofs a hieratic presence as an arrangement of secular temples sitting serenely in the landscape.

The different rooms within the center are organized around a garden patio, or courtyard, typical of Texas vernacular architecture, affording access to the different greenhouses under a shaded arcade, unifying the various buildings. Each room can thus be treated as a separate building, with its own special climatic conditions and spatial configuration. This imparts a processional quality to the sequence of circulation through the conservatory: the entrance pavilion with a symbolic tree; the long, narrow orangery lined with fruit trees; the peaceful fern room with its water cascades and mists; and the rooms with special environments. This procession culminates in the grand palm court where a ramp wraps around the forest of trees, allowing people to move smoothly to the roof where they can view the plants from above, Thus transforming a theoretically small construction into a structure of much grander scale.

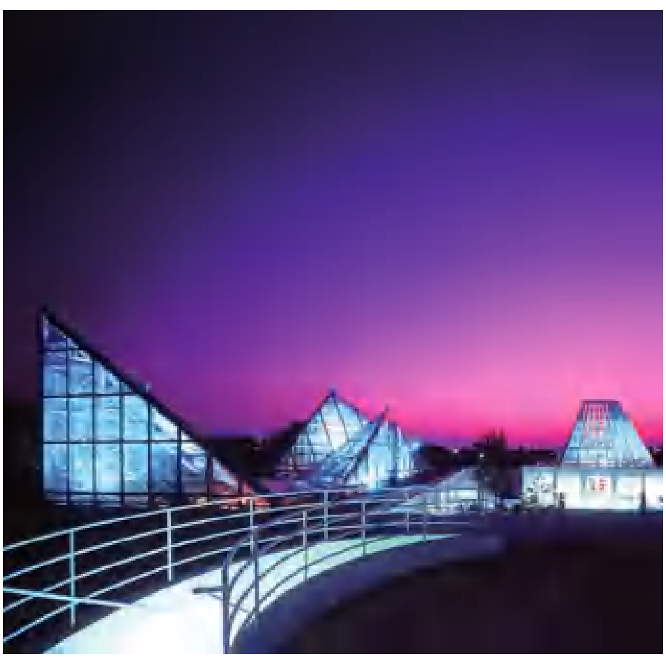
The project provides a unique architectural solution to the problem of designing a greenhouse in a hot, dry climate. While recognizing regional vernacular in organizing the buildings around a courtyard with a shaded arcade, the treatment of the earth as a container and glazing as merely a cover with additional peaks which reduce the amount of sunlight. This allows the complex to harmonize with its surroundings and enhances it with sculptural objects.

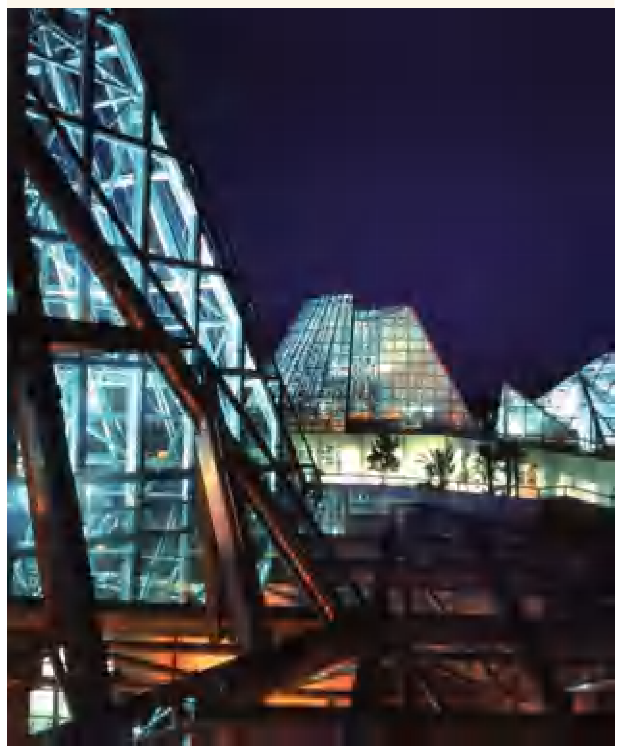
behavior. Not to do so would doom it to failure or would create a great amount of stress and irritation. Newly emerging European society is no longer centered on single authority figures; therefore, their towns no longer should reflect such a political arrangement. As a matter of fact, Japan's emerging new towns have one common feature that makes them very unique to Japan. I am speaking about the fact that many of its towns have developed in the last century around the train station.

In general, European towns developed around the prince or the principal nobleman's palace or the cathedral and its later cities grew from such an organization. In the last 100 years in Europe, the towns created have always reflected the fact that the linking of the new town to the rest of Europe is via the train. Contrary to unfounded assertions repeatedly made, the train will most likely become the most important means of transportation in this century.

The evident example of this is the success of Japan's bullet trains and of its satellite metropolitan networks which connect the bullet train stations with neighboring urban settlements by means of medium and slow speed trains. Therefore, any new Green Town to be created in Europe should build and expand on such a principle, and should be created around the train station. Furthermore, the train station should go beyond its present service as the commercial center of the city to become the Town Hall of the city. It should concentrate in its surroundings all type of public services, ranging from the commercial to the cultural. One possible example of such a new train station can be seen in the design created by the author for a yet to emerge new town in Chiba Prefecture. In this case, the train station area is turned into a vertical green garden (New Town Center, Nishiyachiyo.

The challenge in Nishiyachiyo was to integrate a train station into a commercial and cultural center that feels complete and welcoming. The unique multi-tiered vertical garden which the author designed gives a sense of welcoming arrival and enclosure, establishing visual definitions of the city center, yet screening the surrounding areas. Simultaneously, it establishes a uniform concept for new facades for the town center which will need a clear identity from the very beginning. This new facade is also a green facade composed of open, ivy covered structural





MYCAL CULTURAL AND ATHLETIC CENTER AT SHIN-SANDA HYOGO PREFECTURE, JAPAN

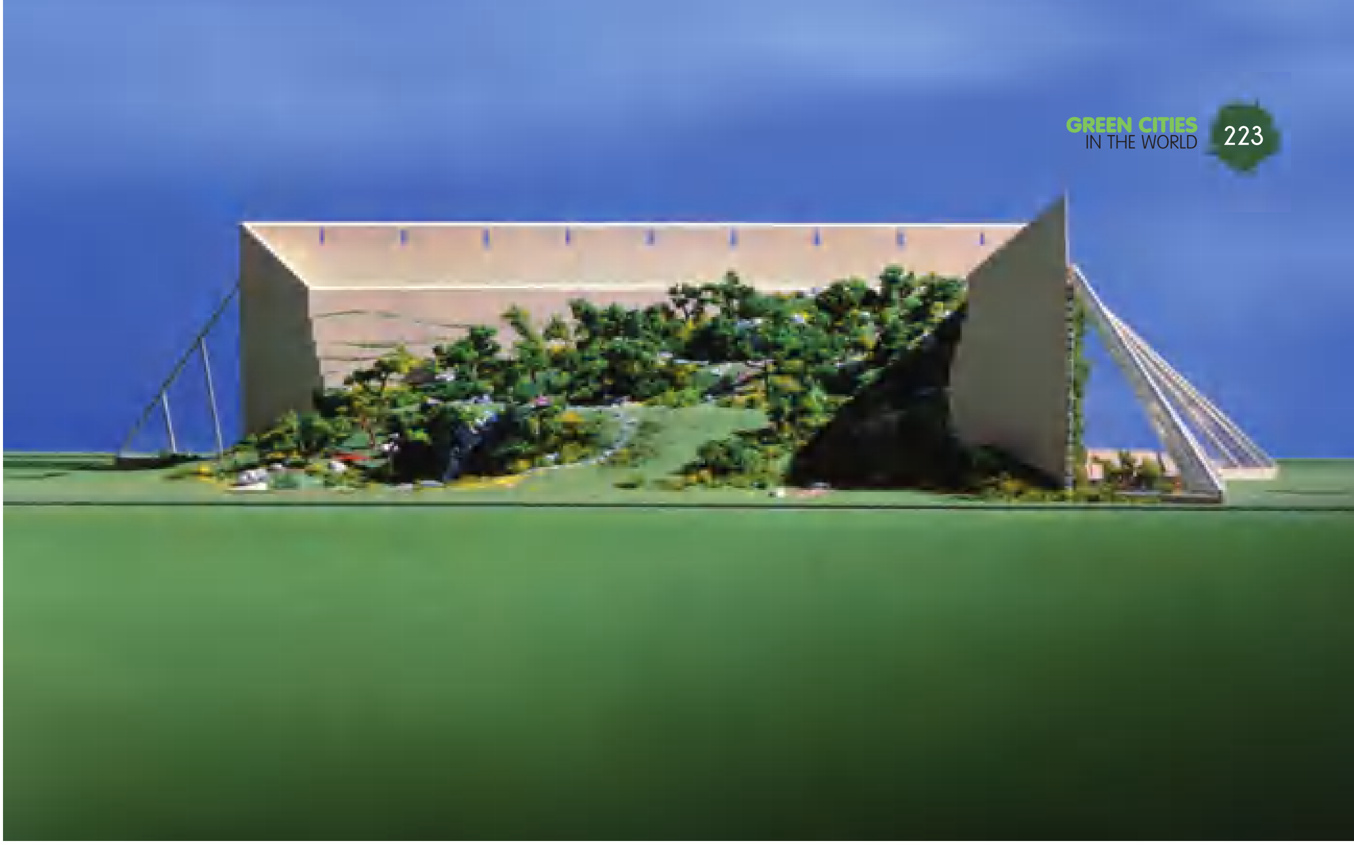
One of Japan's leading department stores commissioned Ambasz to design a cultural and athletic center in the new town of Shin-Sanda to benefit not only its employees but also the growing local community. The new building will contain assembly spaces ranging from small meeting rooms to large multipurpose halls, diverse health and athletic facilities, training centers, guest and hotel accommodations, and underground parking.
The site for this new structure looks across an existing water reservoir to a lush green golf course. The difficult challenge of this site was met by proposing a design concept accommodating the immense massing requirements for the building's 450,000 square feet, yet sympathetically acknowledging the serene open landscape beyond. This design has been conceived as two hands touching at the wrists, as if these hands were both shielding and cherishing the earth. This configuration creates and embraces a new terraced garden, effectively merging the building with the reservoir and green playing fields in the distance.
The entire mass of the building is conceived as a simple, elegant L-shaped wall bracing a garden hillside. The slender exposed building form contains offices and smaller meeting rooms, while the large volumes of the athletic facilities and multipurpose hall lie hidden beneath the garden landscape. A series of reflecting pools begin at the top of the garden and flow from one to the other until reaching the existing water reservoir, seamlessly integrating the new building with the existing landscape.
Simultaneously, skylights within these pools allow natural indirect light to illuminate and complement the screened window views afforded to all of the public gathering spaces within. This outdoor public garden employs traditional landscape techniques, while relating very specifically to local conditions. As in the traditional Japanese "borrowed landscape" garden, the gently stepped planted terraces of Shin-Sanda create a series of secluded gardens for contemplation, relaxation, or watching the setting sun, while enjoying the views to the pond and forest beyond as if the distant landscape belonged to the garden itself.
An undulating linear greenhouse skirting the two visible fronts of the building soften the visible mass of the structure, while protecting its patrons from the noise and activity of the city street. This greenhouse provides an opportunity for the enjoyment of a very different garden space. Warmed by the sun year round, this winter garden is in constant bloom, providing inviting seating areas for the athletic club, the cafe, and public lounge areas. Additional flowers and green plants cascade from planter boxes adorning both facades, as if the garden landscape outdoors has flowed through the building, immersing every level to reach the warm comfort of the enclosed garden within.

grid containing a potted plant in each module which would create a natural, transparent transition between the station and the surrounding town.

In addition, this integrated train station and cultural/commercial center, or New Town Center, will contain a specific set of buildings. There will be, for example, office buildings for very specialized uses like the one the author designed and has been built in the city of Fukuoka. This building covers approximately 13.000 sq. mt. but gives back to the community a multi-tiered, 14-terrace garden of approximately 13.000 sq. mt. The building itself consists of 100.000 sq. mt, of which 60.000 sq. mt. are designated for office space. In addition to the office space the building contains: a 2,500 seat Western-style theater, international conference center equipment and facilities, retail floor space, exhibition center space for Kyushu industries, a government Passport office, and, 500-car parking facilities. This design proposes a powerful type of new solution for the common urban problems found in other cities, that is to say, it reconciles the developer's need for a profitable use of the site with the public's need for open green, garden space.

The plan for the Fukuoka International Prefectural Hall building fulfills both needs in one structure by creating an innovative and powerful synergy of landscape and urban forms. The garden is created through a series of terraces that climb the full height of the building, culminating at a magnificent belvedere that offers a view of the city. Within this structure garden and building conjoin: the building returns to the city the very land it takes away by doubling the size of the existing public space while giving the city of Fukuoka a powerful and symbolic center.

A building such as the Fukuoka International Prefectural Hall, could be a model for other public and cultural buildings to be constructed in the new Green Town. Another such example may be the Mycal Cultural and Athletic Center completed in the new town of Shin-Sanda in the Hyogo Prefecture. It was built on a site that



overlooks a reservoir and a lush, green golf course. This difficult challenge was met by a design concept that accommodates the 45.000 sq. mt. of the building by partially covering many of the facilities with earth and gardens to sympathetically reduce the visual scale of the building, while still affording them light and views. The building forms a simple L-shaped plan that embraces a hillside-like garden to be used in the summer months. There is also an inner winter garden provided to make this building usable year-round. The outer garden has a series of pools, with water flowing from one reflecting pool to the next, until reaching the reservoir. As in the traditional "borrowed landscape" garden, the gently stepped, planted gardens create a series of secluded gardens for contemplation, relaxation or watching the sun. A building of this complexity which in itself contains more than 100 hotel-type rooms could perfectly well be seen as a model for a hotel, as well as a model for a cultural sports facility since the building also houses large swimming pools, basketball courts, and all modes of sport performance. In addition, the building has meeting rooms for close to 1,000 people, a very large number of class rooms with laboratories, and a large variety of differently sized seminar rooms.

The building itself gives back to the community over 75% of the green that it covers. It is a model that could be implemented in a new Green Town. The fact that it has been constructed, and is operating successfully, is living proof of the fact that any problems which may be associated with greenery and earth atop buildings can be easily conquered and that the extra cost that this determines is amply rewarded by community satisfaction and possibilities for further use of the building. This building is a resounding example that it is possible to cover the "gray with the green" and to give back to the community the land which the building covers. In short, it is possible by the author's formula to have the building and the garden.

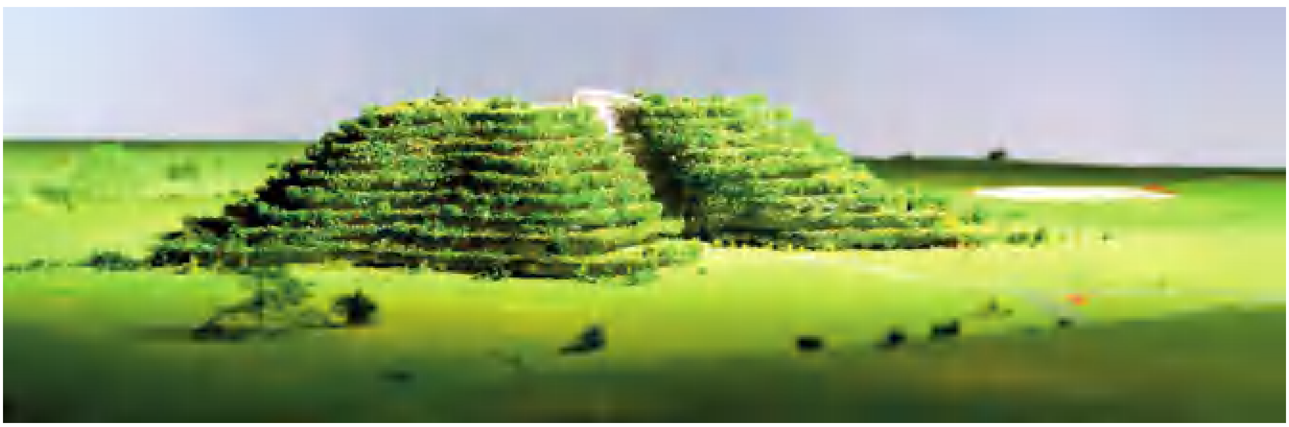
Another example we may want to see reenacted, naturally adapted to meet the requirements of a European new Green Town, is an office building (Worldbridge Trade and Investment Center) which the author has designed for the Baltimore, Maryland (USA) vicinity. It is a 150.000 sq. mt. office building. This nine-story building came about because the neighboring community would not allow any construction that would detrimentally affect their view of the countryside.

The building is, in fact, composed of the gradual stacking of organically shaped floor plates. In the office complex, gardens are cultivated where one plate or balcony extends beyond the next. In addition, the building has an atrium in its center containing a winter garden. Thusly, the building has a garden for all seasons, summer and winter, and when seen from a distance emerging proudly from the land it is seen as a green garden. The real estate advantages of such an office building comes about from the fact that every office has a view, either to the outside landscape or to the inside winter garden. More importantly, it does not impose harsh surfaces upon the community but rather gives them back shade, light, and all changing configurations of a living garden which covers, like the skin on a peach, this very pragmatic type of building. The reader can easily imagine variations of this building utilized not only for the development of office buildings, but also of residential apartment buildings, wherein the apartments would have views to the outside landscape as well as to the inner courtyards place where both children and adults can enjoy a year-round garden atmosphere.

Again, not far from the train station of our proposed new Green Town we can imagine a museum for the city which may be based on the author's design for the Phoenix Museum of History. This is a pilot project in an ambitious revitalization program for the downtown Phoenix area. It nestles within a sloping earth-covered ramp and beneath a new public park. It gives back to the city virtually all the land that would have been taken away by a more traditional design. Rising to a height of

WORLDBRIDGE TRADE AND INVESTMENT CENTER OUTSIDE BALTIMORE, MARYLAND, USA

When the Directors of the Asia/USA Development Corporation began planning a new office complex and trade center, they purchased a suburban site near Baltimore, Maryland. Since the organization's objective is to stimulate trade between the United States and Asia, it was assumed that the design of the new facility would synthesize Eastern and Western traditions—a fitting embodiment of the corporation's intercontinental trade ambitions.
In deriving his proposal, Ambasz considered architectural styles and distinct forms from each culture, but ultimately defied all traditional architecture. Instead, he presented an inventive structure with overt ecological themes—an appropriate modus operandi for today's global culture.
The structures that house Worldbridge comprise two inviting features on the Maryland topography: one, the seeming result of an orchestrated up-lifting at the earth's surface; the other, an implosion forming a carefully wrought cavity. These buildings are, in fact, composed with the graduated stacking of organically shaped floor-plates. A garden is cultivated where one plate extends beyond the next.
The extroverted office complex houses over one million square feet of office space, conference rooms, and a Display Hall organized around a central atrium. The depth of each office floor (a distance measured between an exterior terrace and the interior atrium) is such that views and natural light are available to all.
Regarding this building's atrium, it is one of Emilio Ambasz's most dramatic and monumental interiors. A truncated cone lit from above by an oculus, the base of the space carves a two-story bowl in a highly detailed, highly episodic landscape comprised of rock, moving water, and abundant plant-life.
Adjacent to the superstructure of the office complex is Worldbridge's Exhibition Hall. This 150,000 square foot facility is dedicated to revolving trade shows, and is technically capable of hosting several exhibitions simultaneously while avoiding interference between events. The Exhibition Hall offers a sense of architectural spaciousness through the controlled use of vegetation and the introduction of natural light drawn from its hollowed core.



THE PHOENIX MUSEUM OF HISTORY
PHOENIX, ARIZONA, USA

The Phoenix History Museum is a pilot project in an ambitious revitalization program for downtown Phoenix. The capital of a state famous for its natural beauty, Phoenix is set between mountains and wild, open land. The museum plan integrates the city with its spectacular surroundings by turning the requirement for a large parking lot into an opportunity to bring nature and open public space to the city center.
The museum and the 800-car parking lot, which also serves an adjacent science museum and a museum of historic houses, are set within a sloping structure beneath a new public park. Structural elements are shared beneath this slope by the museum and garage, helping to keep costs within a very limited budget. Rising to a height of fifty feet, the earth-covered ramp shields from view an existing convention center directly behind the site from the pedestrian areas in front of the museum while providing unobstructed views from the park of the surrounding scenery. The museum's galleries, auditorium, classrooms, archives, research library and offices are located on two levels above ground within the slope, the parking areas on several levels above and below ground level. The slope's back wall faces the street and provides access to the loading dock, storage areas and curators' offices. The modest museum gains importance by borrowing from its neighbors' attributes. Its diminutive footprint, disguised by the green slope which stretches principally over the parking area's 275,000 square feet and the small museum's 20,000 square feet, appears more imposing than it actually is. In addition, the building is set back to bring its entrance on axis with a tree-lined street to be flanked with historical buildings as per Ambasz's Master Plan for this Cultural Area.
In response to the museum's focus on the history of the city's early settlers, the site treatment refers to geological history with a terraced rock formation flanking the entrance at the lower end of the landscaped slope, worn away as if by a long extinct stream. Little visible architecture protrudes above the slope save one sinuous wall delineating a free-form L-shape. Like a sheer cliff face, the shorter section of the wall presents a convex mask to the visitor, providing entry through a punched gateway at its base. Passage reveals the facade of the "building" proper formed by the wall's longer section which cups and shades an open air courtyard. Triangular sections of the wall, like the buttresses of the indigenous adobe architecture of the region, protrude into the courtyard, leaving openings that flood the double height gallery behind with light. In counterpoint to this imposing surface is the lacy, undulating colonnade forming the opposite side of the patio and providing light to the library. The two sides of the oval courtyard meet in a circular double-height lobby where visitors experience the sensation of descending deep within the earth upon entry as the slope rises around them.
Like the colonnaded courtyards of the Southwest's Spanish Missions, the enclosed outdoor space contains plants, reflecting pools and fountains. Cool grottoes dripping with water and moss tunnel further into the green ramp behind the colonnade to provide outdoor exhibition space. Its entrance independent of the museum proper, the courtyard can serve after-hours for concerts and other public functions.

15 meters, the earth-covered ramp in front of the museum shields existing construction from view, while still allowing unobstructed views of the park. Also, beneath the garden's covered slope is an 800-car parking garage. Little of the building itself protrudes above the slope; one exception being a wall which delineates a free form that serves as a billboard facade for the museum.

This model of an inclined roof plane-starting at zero level and growing up to, in this case, 15 meters-can certainly be utilized to imagine many other parking or manufacturing buildings created in a similar fashion. There are advantages accruing to this design because, as we well know, parking garages are usually windowless buildings that create a great amount of urban blight and anomie in cities. In the case of our example, three sides of the building are visible to passersby who can see the greenery growing on top of the inclined planed roof, while the fourth side becomes a shopping street, thus maintaining a human connection with the pedestrian while increasing the security of the new Green Town.

We can further imagine creating a man-made lake near our garden town, which could be enjoyed by all the citizens whether for swimming, rowing, or just promenading. Around this man-made lake we can imagine many types of buildings which would provide services to the community while still maintaining the use of the land for the general community. For example, we could imagine having a botanical garden, created in a manner similar to the one built by the author more than two decades ago for the city of San Antonio, Texas USA In this example, all the greenhouses composing this conservatory are covered with earth, except for their tops which are glass roofed. This allows the building to be properly shielded from the elements, as well as reducing

required environmental control equipment. Moreover, it allows the building to not intrude into the ground but, on the contrary, to benefit from the ground. It also allows the visitors the possibility of not only visiting the conservatories at ground level, but also at the roof-top level. They can walk on the grass which grows on the roofs and look at the plants through the glass enclosures. Again, this building is verifiable proof of the fact that using earth on top of building does not create any hardship on the building, but on the contrary, helps to reduce environmental pressures as well as greatly reducing energy consumption since the earth, to a great extent, shields the building from temperature variations.

Also around the lake we can imagine leisure housing, such as described in the project I created for the Shikoku Islands in Japan This lake-centered community would allow the citizens of the Green Town to enjoy water-based leisure activities. It is designed to preserve the beauty of the site for its residence and visitors. While much of the construction is above ground, it is hidden under landscaped earth berms, with gardens flanking the roadway and the canals that weave through the site.

This project takes advantage of the man-made lake of the Green Town and circumscribes the site by means of the canal. There could also be a second major canal through the middle of the site with an intricate network of secondary waterways feeding off it. The community is organized in this case into two zones. The outer zone is defined by the perimeter canal and the center canal that laces through the site. This zone would become the exclusive domain of privately owned houses. The area between the new man-made lake and the canals would be a non-residential zone which can consist of hotels, shopping areas, restaurants, recreation facilities, parks and promenades, as well as a lake marina.

This type of design for residential quarters would provide both a maximum level of privacy between the houses as well as offer contact with nature, despite the density of the community. The houses can be hidden by lushly landscaped walls on two of the side walls; the roofs can also be landscaped so that when viewed from afar they would present a continuous green surface.

The more public sections of development, which would comprise the lake beach, would be focused around the marina. This marina is to be anchored on one end with a 200-suite hotel connected to a covered arcade that winds along the length of the boat basin; the arcade could be fronted with retail shopping. As in the case of the Worldbridge building, the hotel could step back at each floor to create hanging gardens culminating in a roof terrace. The exterior surface of the hotel building would, therefore, become alive and green. The outside surface of the other structures in this quarter can also be landscaped, like the residential community, that the shared facilities would present a green botanical facade when viewed from the streets.

The Green Town should also be able to house research laboratories and, to that effect, the author suggests the use, albeit modified, of his design for the Schlumberger facilities located on the edges of Austin, Texas USA (Schlumberger Research Laboratories). In this case, the site for this computer research facility is maintained as a green landscape as it would be valued by the surrounding community as a beautiful, green park land. Thus it was possible to create the design that harmonizes with the landscape rather than standing out against it.

The project was divided into a series of smaller buildings with earth berms built against the walls to help integrate them into the landscape and, simultaneously, reduce energy costs. In this way, the neighbors see a beautiful man-made landscape rather than intrusive buildings. The buildings and recreations facilities at this research facility are arranged casually around the man-made lake in the manner of an English landscaped garden. Notwithstanding the fact that the architecture is built above ground, because of the earth berms covering its

SCHLUMBERGER RESEARCH LABORATORIES
AUSTIN, TEXAS

The program for this computer research facility, to be built on a site outside Austin required a laboratory that could adapt readily to changes in research-group size, and which would promote communication between individuals and groups. The solution offered a laboratory layout that met the client's programmatic needs while at the same time taking advantage of the building's site.

Because the site warranted a design that harmonized with the landscape rather than standing out against it, the project was divided into a series of smaller buildings with earth berms built up against them to help integrate them into the landscape, reduce energy costs, and provide the client the campus atmosphere requested. The buildings and recreational facilities are arranged casually around a man-made lake, in the manner of an English landscape garden. The buildings, because of the earth berms, blend into their surroundings, and provide a pleasant atmosphere for employees while taking advantage of the pleasant vistas.

Furthermore, the separation of the buildings encourages workers to go out and experience the landscape, rather than simply observe it from an office window.

The laboratory design proposes a new type in the development of such spaces. It consists of a large, undifferentiated space in which the researchers' offices — 9x9 foot mobile units — would be placed. The units, which contain desks and shelves, are totally enclosed, except for a door and window on opposite sides. The researcher has complete control over the lighting, acoustics, and temperature of his unit, and he also enjoys the privacy of a more traditional office. The mobile units may be moved quickly and easily by forklift to a new location to accommodate any group size and configuration. The proximity of these units and the common space that results from their arrangement fosters communication within the research group.

The laboratory design incorporates the best characteristics of the open office landscape -- flexibility and ease of communication -- with those of the traditional office, such as reduced noise levels, individual control of the environment, privacy, and a sense of permanence.

walls, it blends into the surroundings while providing a pleasant atmosphere for employees wishing to take advantage of the pleasant vistas. In this case, again, the laboratory buildings give back to the community all the ground that they cover. It represents another example of how it is possible to create Green Towns which are essentially green and where nature and building are two aspects of the man-made endeavor.

This brings us to a philosophic question: we have to redefine what is nature and what is man-made nature. In a situation such as the global one where a tree exists either because someone planted it or because someone decided to leave it there, it is imperative that we create a new philosophical definition of what we mean by man-made nature. Such a definition would have to incorporate and expand not only on the creation of gardens and public spaces but also on the creation of architecture which must be seen as one component aspect of the making of a man-made nature. The author proposes that such new Green Towns can be created in Europe as an example of its advanced society, and at the same time, as a reflection of its deep-seated cultural respect for nature. Few other cultures have carried their respect for nature to such a sophisticated degree. The concepts for a new Green Town the author here proposes may allow Europe to become the exemplary creator of new urban settlements, becoming the wonder of the world, and, more importantly, a paradise.

3. ARS POETICA

• We must create alternative images proposing a better life to guide our actions if we do not wish to perpetuate present conditions. I believe that any architectural project not attempting to propose new, or better, modes of existence is unethical. This task may stagger the imagination and paralyze hope, but we cannot subtract ourselves from its pursuit.

• I've never been so much a man of leanings, as much as I have always been a man concerned with going forward. I have always striven in my work to present alternative models of the future so that we can change the present. This is a task that has me dedicated in heart and mind.

• My existential wager is on poetry, and a commitment to justice is, for me, one of the necessary, but not sufficient conditions to achieve such a high plateau.

Justice, whether social or moral, is a conceit of the mind. Justice does not exist in nature, but despite this cruel fact, I feel very strongly that it is our ethical imperative to pursue its implementation on earth. Even if we know it to be a delicate structure, held together by such ethereal material as abnegation and altruism but destined to collapse at night, we must every new morning re-build it.

• If there is any strength to my architectural ideas, it comes from the fact that I believe that architecture has to be not only pragmatic but also move the heart.

• I rejoice immensely when I come upon somebody else's work that touches me, even if it is the architecture of someone like Gehry, for example, whose work is so different from mine, and whose concerns are totally unrelated to mine. What matters to me is that he sings his own song. His birds may not alight often in my garden, but I'm sure they will pollinate even my own flowers.

• There is in all of us a deep need for ritual, for ceremony and procession, magical garments and gestures. It is an archetypal quest in which all partake.

• I understand architecture as the search for a spiritual abode. On the one hand, I am playing with the pragmatic elements that come from my time, such as technology. On the other hand, I am proposing a certain mode of existence that is an alternative, a new one. My work is a search for giving architectural forms to primal things – being born, being in love, and dying. They have to do with existence on an emotional, passionate, and essential level. Perhaps, I use very austere elements to express this quest and, therefore, the gesture may be seen as an austere one also. But by doing it in this way, I believe that it may be far more durable. I am interested in the passionate and the emotional when they assume a timeless guise.

• I seek to develop an architectural vocabulary outside the canonical tradition of architecture. It is an architecture that is both here and not here. With it I hope to place the user in a new state of existence, a celebration of human majesty, thought, and sensation. Though apparently quite new, there are devices – both primitive and ancient – permeating the designs. The result is an architecture that seeks to stand for eternity.

• The ideal gesture would be to arrive at a plot of land so immensely fertile and welcoming that, slowly, the land would assume a shape – providing us with an abode. And within this abode – being such a magic space – it would never rain, nor would there ever be hardships of any other sort. We must build our house on earth only because we are not welcome on the land. Every act of construction is a defiance of nature. In a perfect nature, we would not need houses.

• If one finds the quintessence of a problem, one will have better access to an irreducible solution. The thread supporting my design quest in every area – my products and my architecture – is a single preoccupation: finding the root of the problem, its essence.

As for expressive means, I seek to approach a design problem in the most crystalline, austere, and graceful manner. I long for an architecture which has been reduced to essentials and which, at the same time, is architecture full of potential meanings. Such concision is the method to achieve a multi-dimensional, epigrammatic architecture.

• My quest for the essential in architecture is not about being simple and light like a feather; it is about being essential and concise, like a bird.

• I am only interested in discovery, not in recovery; I am keen on invention, not on classification. In the uncharted realm of invention, taxonomy is a process yet to be born. In the same way, as I search for essential and lasting principles in architecture, in opting to write fables rather than write theoretical essays I may have grasped something basic: fables remain immutable long after theories have crumbled. The invention of fables is central to my working methods and it is not just a literary accessory. The subtext of a fable, after all, is a ritual and it is to the support of rituals that most of my work addresses itself.

• From where, or whom, came the idea that pastoral fields existed historically only outside the city walls? To this day, one can go up to the top of the towers of a medieval city like Bologna, and discover that behind the facades defining treeless streets exist immense gardens which occupy almost 25% of the city's area. Those were once vegetable gardens and places where cows grazed. Those grounds were of outmost importance to survive a siege.

• I strive for an urban future where one can open your door and walk out directly on a garden, regardless of how high your apartment may be. I submit it that my building in Fukuoka is one example of how we can, within a high-density city, reconcile our need for building shelters with our emotional requirement for greenery.

• I am inescapably the child of my time, and, therefore, distrustful of making irretrievable formal statements, thusly I use elements that change with the seasons. The leaves fall in autumn allowing the sun to warm the walls, after having shaded it from the heat in the summer. It is an adornment, indeed, but it is intrinsic to the building, just like breathing skin is to an organism. When marble leaves and garlands fall to the ground or end up in museums, the building is scared but its usefulness survives. If the plants covering my buildings are torn off the building suffers a substantial reduction of its raison d'etre. If these plants had been just an added-on ornament, removing these from the building would detract from its visual characteristics, but not from the buildings integrity and performance.

• If Nature were to have welcomed us in the guise we have become, we would have needed to make no shelter. I believe that in our pursuit to master Nature-as-found, we have created a second man-made-Nature, intricately related to the given-Nature. We need to re-define architecture as one aspect of our man-made nature, but to do so we need first to re-define the contemporary meaning of Nature. Perhaps a new Philosophic Academy is what is called for. Shall we call such institution a Universitas, i.e. the whole?

• Convinced that architecture should be the work of someone else's imagination, some celebrated architectural contributors to a marketplace culture re-propose good old Neo-Modernism 101 - tilted, twisted, and fragmented; over squeezed and left for dead, but still juicy - as the easily disposable clothes to dress chapels a la mode for those believers in "I consume, ergo sum."

• If an architectural work does not move the heart what is the point of it; it is just one more building. I am not ashamed to say I pursue the transcendental in my work. It is ungraspable and elusive, but I am devotedly convinced it can be evoked. I sometimes fancy it passing through me. On those occasions I have felt as if it was carrying me away.

• The so-called Green Movement is a big umbrella where, at present, I wouldn't dare to cast too much light because the shadows are still looking for their bodies. It is a state of awareness; it doesn't yet constitute a conceptual reality because it lacks a precise system of discourse and a theoretical structure that will allow it to transmit a body of knowledge, and to constantly re-evaluate it. It is an attitude, so far.

• Fukuoka demonstrates that one can have the " green and the gray " - one on top of the other - and at the same time one can give back to the community 100% of the ground that the building's footprint covers in the form of gardens accessible from the ground floor to everyone. This building is, for me, very strong evidence that the prevailing notion: "the cities are for the buildings and the outskirts are for the parks; " is a mistaken and narrow-minded idea. The Fukuoka building demonstrates, once and for all, that one can have a building and the garden, 100% of the building, and 100% of the greenery the building's users and its neighbors long for.

4. CONCLUSIONS

Naturally, such a presentation as this one, given the small space available for detail, can only be schematic at best. The idea of Green Towns are a magnificent opportunity for Europe to give a uniquely European answer to the problem of a society's urbanization process as it passes from a secondary and tertiary type of economy onto a quaternary level, concerned with the creation and utilization of Information.

The author attaches examples of some of his work to illustrate his concept and begs the reader's forgiveness for presuming that these projects contain within themselves the genus of a solution.

CHAPTER 14
GREEN ROOFS AND WATER MANAGEMENT

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ABSTRACT

Healthy plants have a major impact on the economic and ecological benefits that green roofs can provide. However, water availability is often the limiting factor in keeping plants healthy, especially on extensive green roofs. Water management strategies include a combination of growing substrate characteristics (both composition and depth), plant selection, plant canopy coverage, desired goals for controlling stomwater runoff, evapotranspiration, and irrigation practices. These factors are all interconnected with environmental conditions on the roof such as temperature, irradiance levels, and rainfall amount and distribution. The following chapter discusses how managing these factors can influence the water balance and success of green roofs.

KEY WORDS

Crassulacean acid metabolism, evapotranspiration, growing media, growing substrates, sedum, succulents, stormwater runoff, transpiration, water retention

1. INTRODUCTION

Water management factors such as plant selection, substrate composition and depth, roof slope and orientation, climate, microclimate, plant canopy cover will all influence water retention, evapotranspiration, heat flux, and how well a green roof functions. In order to manage water on an individual roof, one must define the purpose and objectives of the green roof. Many of the known benefits such as reduced stormwater runoff, a reduction in energy consumption, habitat for wildlife, and aesthetics can all complement or contradict each other. What is the main function of the roof? Was it constructed to save energy, reduce stormwater runoff, grow vegetables or provide habitat for wildlife? Can urban farming be done without supplemental irrigation? All of these functions depend on water management. Four main topics associated with water management are growing substrates, stormwater management and heat flux, evapotranspiration, and irrigation. These are all discussed in relation to plants.

2. SUBSTRATES

Growing substrates (media) are a major component of a green roof. In addition to physically supporting the plants and providing nutrients, it plays a critical role in water management. Water retention can be manipulated by altering substrate components and by changing depth. Plant selection can also influence water retention, although plant species are usually chosen based on the given

Chicago Bank of America. Source: Greenroofs.com; Photo Courtesy: Green Roof Blocks.

substrate composition and depth along with other environmental factors. The ideal substrate must be able to sustain plant life while providing for the physical, chemical, and biological needs of the plants, be lightweight enough to stay within the load bearing capacity of the building, possess adequate water and nutrient holding capacity, be course enough to allow for drainage while not leaching pollutants in the runoff, not break down over time, and be sourced from locally available materials.

Physical properties of substrates include bulk density, pore space, water holding capacity, container or field capacity, and capillary water rise. These are the main properties that determine stormwater retention as well as available air and moisture for the plants. Bulk density is defined as mass per unit volume. When calculating weight on green roofs, one must include the maximum additional weight of the retained water when all the pore space is saturated. Aerated pore space is the portion of the substrate that is filled with air at container capacity. It is expressed as a percent of the total volume and is ideally at about 20%. The optimal percentage depends on plant species. Succulents such as *Sedum* spp. require well aerated substrates as too much water can be detrimental. As aerated pore space increases, water holding capacity decreases and vice versa. Field or container capacity is the quantity of water remaining in the substrate after it has been allowed to drain by gravity. Field capacity and container capacity are often used interchangeably, but the interface between the substrate and the bottom of the container (the roof in this case) has a zone of saturation where water is more tightly held. In the field there is generally not a lower barrier so water can drain more freely. For this reason, engineered substrates will usually be coarser to allow for drainage.

Chemical properties of substrates include such factors as pH, cation exchange capacity (CEC), and nutrient content. They are associated with plant growth and have little to do with stormwater retention. However, leaching of nutrients and other chemicals can pollute runoff if not managed correctly. Plants need several essential nutrients to survive and grow. These nutrients are usually present in sufficient amounts in field soils, but are often lacking in engineered green roof substrates. Field soils, especially those with clay, usually have a high CEC which retains positively charged nutrients. Cations are positively charged ions such as potassium (K+), magnesium (Mg++), and calcium (Ca++) which are attracted and held by negatively charged soil particles and then released slowly over time. Course green roof substrates generally have a low CEC so cations are not held in the soil, but instead leach though in the runoff. Adding clay can increase the CEC, but may result in the fine clay particles moving to the bottom and clogging drainage systems. Adding organic matter will increase CEC as well as providing nutrients as it decomposes, but must be kept within certain percentages.

If nutrients are deficient, an application of organic or inorganic fertilizers can be added to provide nutrients. On green roofs, soluble fertilizers should not be used as the nutrients will be lost through leaching in a short period of time due to the coarse substrate, shallow depth, and low CEC. The level of fertility to maintain depends on the plants being grown and the purpose of the roof. Succulents such as *Sedum* require relatively low fertility, whereas vegetables require high nutrient levels if a crop is to be harvested. FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau) recommends fertilizing extensive green roofs with a controlled release NPK fertilizer at the rate of 5 g/m^2 of N (FLL, 2008).

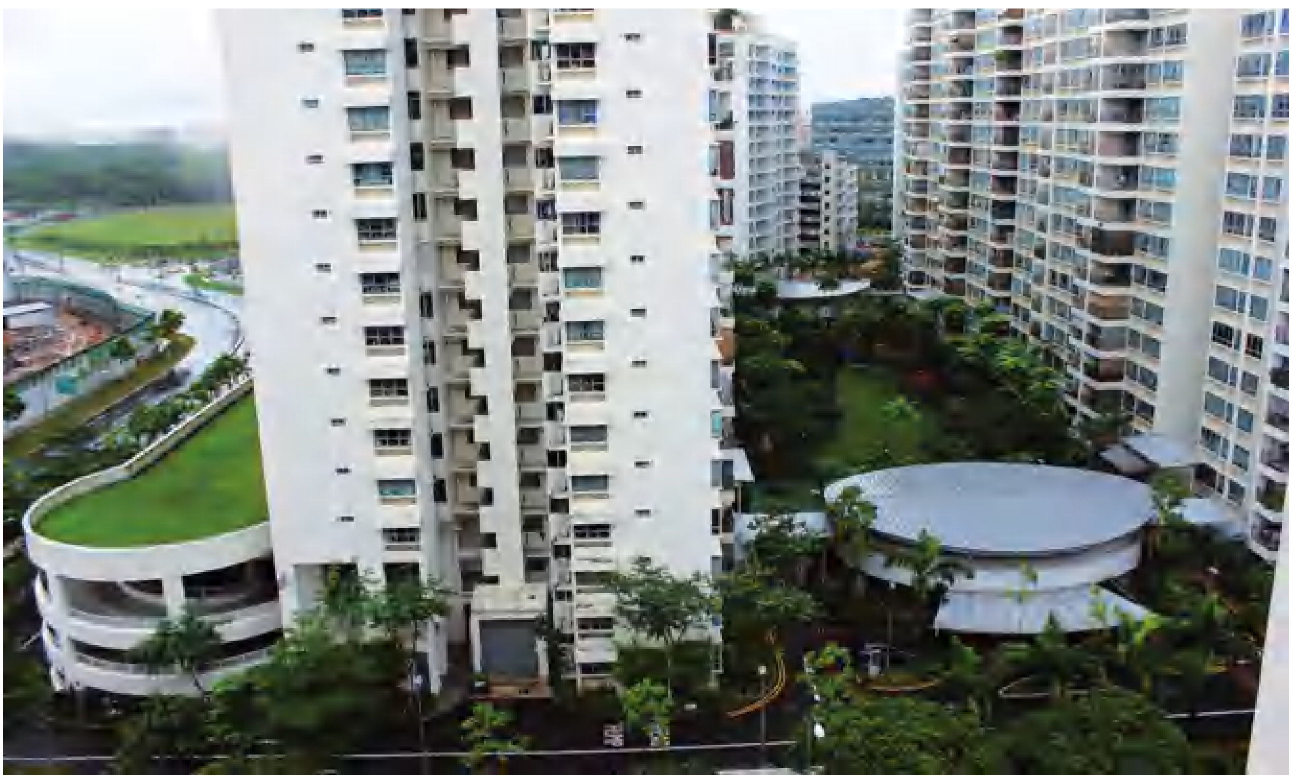
Numerous studies have evaluated the role of controlled release fertilizers in the nursery and greenhouse industries for containerized plants. The primary goal for plant production in the nursery is to push growth and produce a healthy marketable plant as quickly as possible. In contrast to containerized nursery stock in a production schedule, maximum growth is not always desirable on a green roof. Lush growth results in greater biomass and is more vulnerable to drought conditions that are often present in rooftop environments. Ideally, a green roof fertilizer application schedule would utilize enough nutrients to maintain acceptable plant health and aesthetics while minimizing the amount of runoff contamination.

The Espace Aquatique de Morzine. France. Source: Greenroofs.com; Photo Courtesy: Le Prieuré Vegetal i.D.®

The biological component of a green roof substrate revolves around organic matter. Organic matter added to the original substrate will eventually break down as well as decomposing plant parts such as roots and leaves. The substrate will eventually reach an equilibrium at around 2 to 5% (by volume) depending on the local climate. Decomposition will be slower in colder and more arid areas, but can be relatively rapid in hot, humid climes. Most plants prefer substrates with high organic matter content as it improves water holding capacity and CEC. However, the total amount of organic matter should be kept below 20% in most cases. It may also be a source of pollutants as nutrients leach into the runoff. If too much organic matter is included in the substrate mix, the substrate depth will decrease as it decomposes until a stable equilibrium is reached. A shallower depth will result in stressed plants since they were specified for a deeper depth. It is also usually not practical to continually replace substrate on a rooftop. The biological portion of the substrate also includes plant pathogens, insects, microbes, and fungi. Healthy soils are living organisms in themselves.

Substrate Composition. Rather than utilizing natural soils, green roof substrates are usually engineered. This is due in part because natural soils are so variable and nearly impossible to duplicate on a consistent basis. It would very difficult for a commercial green roof company to duplicate the exact substrate from roof to roof and even within the same roof. In addition, natural soils may not be coarse enough to provide adequate drainage. They range in particle size distribution from rocks to sand to clay and possess different percentages and types of organic matter. Even so, adding natural soils to a substrate mix can add fungal organisms, insects, and other natural microbes that can lead to a healthier growth substrate.

Because of the drainage and consistency issues, engineered substrates are often a combination of mineral based aggregates mixed with a fraction of organic matter. Examples of inorganic mineral components include aggregate materials such as heat expanded slate, shale, and clay,



Roof garden of a newer style on a condominium in Singapore. Source: M. Köhler.

Roof gardens and infinity pool, iconic places (Singapore). Source: M. Köhler.

volcanic pumice, and sand. With the exception of sand, all are relatively lightweight, promote good drainage if formulated with the correct particle size distribution, and are stable. While these inorganic components provide structure, allow for drainage, and resist compaction, organic matter such as compost, peat moss, or coconut coir is also blended with the initial substrate mix to increase water holding capacity and provide nutrients.

Rowe et al. (2006) compared five substrate compositions containing 60, 70, 80, 90, and 100% of heat-expanded slate to evaluate the establishment, growth, and survival of two stonecrops (*Sedum* spp.) and six native herbaceous perennials and grasses. Grown in 10 cm of substrate without any supplemental irrigation, the higher percentages of heat-expanded slate in the substrate resulted in less growth and lower visual ratings across all species. By the end of three years, the majority of the herbaceous perennials and grasses were dead, but both stonecrops achieved 100% coverage after one season and maintained this coverage throughout the study. Results suggest that moderately high levels of heat-expanded slate (up to 80%) can be incorporated into a green roof growing substrate when growing succulents such as stonecrop, without sacrificing plant health and at the same time reducing the load placed on a building. However, the non-succulents used in this study require deeper substrates, additional organic matter, or supplemental irrigation in order to survive.

The pursuit of alternative green roof substrates is important ecologically. Producing heat expanded aggregates is an energy intensive process as the raw materials are harvested from strip mining operations and then processed in rotary kilns. Getter et al (2009) reported that 80% of the embodied energy in a standard substrate was accounted for by the heat-expanded slate. Alternative components such as recycled-tire crumb rubber, foam and

Integrated system with plants in the ground or roof level as rain gardens. Source: M. Köhler.

fiberglass, waste clay from excavations, fly ash, sewage sludge, paper ash from recycled newspapers, and carbonated limestone from quarry fines have all been tried with various degrees of success. However, there is still a need to explore the use of recycled and sustainable materials as substrates and to reduce the carbon footprint required to produce them.

There is also a need to determine the optimal types and percentages of compost in green roof substrates. Complicating matters is the fact that compost can be very different depending on the maturity of the compost as well as the feedstocks and methods used to make it. The benefits of using compost are well known as it helps maintain good soil structure, increases CEC, improves water retention, and provides a steady, though limited, supply of N, P, and S to the plants through mineralization. Regardless, organic matter should be kept to a minimum on green roofs because it breaks down over time and causes the substrate to shrink. The German FLL standards recommend 4–8% organic matter by volume for extensive green roofs (FLL, 2008). Even so, this must be balanced so that N and P leaching does not become a significant pollutant in runoff (Rowe, 2011) and so pH and mineral balance are maintained.

High levels of organic matter or the addition of fertilizer to the substrate can also result in a substrate that is too fertile. High fertility will encourage lush growth that is more subject to the inevitable drought stress on roofs that are not irrigated. Rowe et al. (2006) found that plants of *Aster laevis*, *Koeleria macrantha*, and *Solidago speciosa* survived in greater numbers when they were not fertilized. The lower fertility resulted in less biomass that needed to be maintained which in turn enabled these plants to survive drought conditions for a longer period of time. The exception would be roofs that are producing vegetables for harvest. Furthermore, substrates with a low to medium fertility level may encourage a more diverse plant community, reducing the likelihood of dominant aggressive species. As with compost, applying the minimal amount of nutrients to maintain plant health lessens the potential for contaminated discharge of N, P, and other nutrients from green roofs.

Regardless of the materials used to formulate a green roof substrate, the finished substrate should fall within the FLL standards for green roofs. The German FLL standards are based on years of experience with green roofs and include standards for mineral content by volume, granulometric distribution, organic content, frost resistance, structural and bedding stability of aggregate-type materials, behavior of substrate boards under compression, water permeability, water storage capacity/maximum water capacity, air content, pH, carbonate content, salt content, nutrient content, adsorptive capacity, C/N ratio, content in respect of seeds capable of germination and of plant parts capable of regeneration, and behavior under fire. Substrate composition will ultimately depend on what materials are available locally and can be formulated for the intended purpose of the roof, plant selection, climatic zone, and anticipated level of maintenance.

Substrate depth. In addition to composition, substrate depth has a major impact on volumetric moisture content and water retention. Given the same substrate blend, a shallower substrate will not be capable of retaining as much water and the water that is retained will be lost through evapotranspiration in a shorter period of time. The lack of substrate volume also limits rooting depth and access to the water and nutrients that are present. Periods of drought can be very stressful and possibly lethal to plants, depending on initial plant selection which is why drought tolerant succulents such as sedum are often specified for shallow extensive green roofs. If herbaceous perennials and grasses are specified, then deeper substrates or irrigation must be an option during periods of drought. In contrast, the lack of substrate moisture in shallow substrates can be a method of weed control. Most herbaceous weeds will not be able to survive extended drought periods, whereas succulents can be very tolerant of drought conditions.

Scientific studies investigating the effect of substrate depth have found that greater depths increase survival percentages, growth rates, and the diversity of species that can be established. This is particularly important when viewing green roofs as a means of restoring natural habitats (Lundholm et al., 2010) as shallow planting beds may not be capable of supporting local flora. Research at Michigan State University has shown that substrate depth influences plant growth, substrate coverage, and long-term plant communities regardless of species (Monterusso et al., 2005; Rowe and Getter, 2010; Rowe et al., 2006; Rowe et al., 2012). Deeper substrates increased water holding capacity and served as a buffer for overwintering survival as shallow substrates are more subject to fluctuations in temperature. Shallow depths are more likely to experience temperature fluctuations which can harm root systems as the roots of many species are the most susceptible to cold damage. Despite the cultural limitations of shallow substrate depths, they are often desirable for practical reasons as buildings must be structurally strong enough to support the added weight of a green roof.

At the University of Sheffield, Dunnett et al. (2008) found that a depth of 20 cm resulted in greater plant survival, diversity, and flowering performance compared to a depth of 10 cm. Species-richness (mean number of taxa per subplot) decreased over the six year study period at both substrate depths, but the rate of decline was greater at 10 cm. However, deeper depth is not beneficial for all species as some performed better at a depth of 10 cm and others at 20 cm. Low-growing succulent species such

Water recycling station. Valdemingomez. Madrid. Spain.

as sedum thrived at a depth of 10 cm, but were not as competitive at 20 cm. Likewise, the perennial plants that normally possess greater biomass could not survive as well at 10 cm, but could easily outcompete sedum at 20 cm.

There are two ways to increase substrate depth: structurally modifying roofs to increase load capacity or decreasing the bulk density of the substrate. Structural modification is an obvious economic barrier to green roof implementation, thus it is logical to pursue alternative substrate options.

3. STORMWATER RETENTION AND HEAT FLUX

It is well known that green roofs can reduce stormwater runoff and in many areas of the world they are implemented as part of a stormwater management plan. In a green roof system, much of the precipitation is captured in the media or vegetation and will eventually evaporate from the soil surface or will be released back into the atmosphere by transpiration. Water retention depends on design factors such as substrate depth, composition, roof slope, and plant species, as well as pre-existing substrate moisture and the intensity and duration of rainfall. In addition, runoff is delayed because it takes time for the media to become saturated and for the water to drain through the media.

Vegetation can influence stormwater retention, runoff water quality, and building energy efficiency (heat flux). Plant canopies intercept rainfall, shade the roof thus reducing evaporation from the soil, and transpire. A study in England compared grasses, forbs, and sedum, and reported that the grasses were most effective in reducing stormwater runoff followed by the forbs. However, *Sedum rupestre* and *Sedum spurium* 'Coccineum' with their

Integrated Green infrastructure. Source: M. Köhler.

upright structure reduced runoff more than creeping species such as *Sedum acre* and *Sedum album* (Dunnett et al., 2008). Species possessing greater height and diameter were associated with less runoff. Both stormwater retention and heat flux are partially a function of evapotranspiration.

4. EVAPOTRANSPIRATION

Evapotranspiration is the sum of water transpired through plants and water that evaporates from the soil surface. Transpiration is dependent on the vapor pressure gradient between the intercellular spaces within leaves and the surrounding atmosphere. It also depends of plant species and total plant biomass, in particular leaf surface area. Likewise, evaporation from the soil is dependent on existing soil moisture and shading from plant cover. Both are highly dependent on temperature, humidity, and irradiance levels. Evapotranspiration rates can influence volumetric moisture content and thus plant health and survival, the ability of a green roof to retain stormwater, and heat flux into and out of a building. It is a factor that should be included in both hydrologic and energy models for green roofs.

It is thought that plants that possess high rates of transpiration will dry out substrates faster and thus provide greater stormwater retention capacity between rain events. However, high transpiration rates are dependent on available moisture and if moisture is not available, these species will be stressed or die. That is why succulents such as sedum are often specified for shallow extensive green roofs due to their drought tolerance. They can limit transpiration and store a greater amount of water in their tissues. Studies have shown that many species of *Sedum* can survive up to two years without water (VanWoert et al., 2005). *Sedum acre, S. kamtschaticum ellacombianum, S. pulchellum, S. reflexum*, and *S. spurium* all survived 88 days and *S. rubrotinctum* was found to survive at least two years without water in a greenhouse. Other succulents such as *Delosperma, Euphorbia*, and *Sempervivum* possess many of the same characteristics.

The majority of plant species exhibit C3 metabolism, meaning that CO^2 is taken in through open stomata in the leaves during the day. Through the process of photosynthesis this carbon is converted to sugars and plant tissue for growth. Although efficient, C3 plants require relatively more water as water is lost during transpiration through the open stomata. Under drought conditions, these plant continue to lose water which will eventually have an impact on plant health and survival. In contrast, plants that exhibit Crassulacean Acid Metabolism (CAM) have the ability take up CO^2 during the night, store it in cell vacuoles, and then use it the following day in a normal photosynthetic carbon reduction cycle. The advantage these plant possess is that they have the ability to close their stomata during the day when the greatest vapor pressure gradient exists, thus reducing water loss. Instead stomata are open during the night. Many succulents such as *Sedum* spp. exhibit some form of CAM which makes them ideally suited for extensive green roofs.

With the current trend to specify more native herbaceous perennials and grasses instead of succulents for green roofs, there is potential to increase transpiration on rooftops. One problem with specifying these native plants is that the artificial engineered environments that are often placed on roofs are not native environments and are usually quite different from what is found at ground level. Still there are many benefits such as increased biodiversity that can be gained by using plant material other than succulents, even if they are not native. When 18 different native herbaceous perennials and grasses grown in 10 cm of substrate in Michigan, only four species still existed after four years (Monterusso et al., 2005). The plant species tested were chosen because of their drought tolerance, but some rely on deep tap roots to obtain moisture in their native environment. In a shallow extensive roof, these roots can still grow sideways, but periods of drought resulted in death without supplemental irrigation. Providing deeper growing substrates or supplemental irrigation could maintain substrate moisture so that high transpiration rates would not be a problem.

The next series of questions involve the effect of evapotranspiration on recharging the stormwater retention capacity and energy conservation properties of a green roof. What role does vegetation play in water retention? Is there a difference between bare substrate and vegetation cover? How much does transpiration rate influence the ability of a roof to dry out the substrate so it can retain more water when the next rain event occurs? Does plant species matter?

VanWoert et al. (2005a) compared bare substrate to a sedum vegetation. In both cases 2.5 cm of substrate was placed over a 0.75 cm thick water retention fabric. Of the 83 measured rain events that occurred over the 14 month test period, the vegetated roof and substrate only treatments retained 60.6% and 50.4%, respectively. In this study they concluded that vegetation did not have as great an impact on water retention as expected and suggested that the main factor for water retention is the physical properties of the substrate. In this shallow system, the water retention fabric accounted for 40% of the depth and likely played a significant role.

Berghage et al. (2009) found that water use was greater in planted systems of *Sedum album* and *Delosperma nubigenum* compared to bare substrate. When the plants were supplied with adequate moisture, ET was 10.5 mm/day, or about 40% of the field capacity moisture. During a 14-day dry down period, average ET was only 0.036 cm/day. During this period, 6 mm of water was lost through evaporation from the bare substrate, while 10 mm was lost from planted systems. When there was ample moisture, ET was similar for both systems, but as the substrate dried, water stored in the plants and their ability to extract moisture through their roots resulted in greater ET for the planted systems.The drought tolerant succulents also transpired readily when water was available, but conserved water as the substrate dried. It was also noteworthy that when there was ample moisture, ET during the day exceeded water loss at night for both planted and bare substrate. As the surface of the bare substrate dried out, ET dropped, but ET in the planted system remained relatively stable. After 3 to 4 days, ET dropped in the planted system during the day, but continued to lose water during the night which it what one would expect for CAM plants. After 7 to 8 days without water, ET became negligible as the plants became increasing water stressed.

In another study, VanWoert et al (2005b) measured growth, survival, volumetric moisture content, and ET for a mixture of sedum in three substrate types: (1) depth = 2 cm, (2) depth = 2 cm on a 0.75 cm water retention fabric, and (3) depth = 6 cm. Following an establishment period, plants and a bare substrate treatment were subjected to watering regimes of 2, 7, 14, 28, or 88 days between watering. Substrate moisture levels of the planted treatments were typically higher than those with bare substrate within respective substrate designs. In addition, the deeper substrate treatment consistently contained the highest substrate moisture across all watering regimes, however, it was only significantly different under watering regimes of 2 and 7 DBW. The higher substrate moisture levels for the vegetated treatments are presumably due to the shade provided by the plant canopy which decreased evaporation from the substrate surface. Evapotranspiration was highest on the day of watering and decreased daily until leveling off at 0 mm/day. This occurred two days after watering for the 2 cm deep substrate and after seven days for the 2 cm + fabric and 6 cm deep substrates. In general, the deep substrate maintained the highest ET rate. Over the 88 day study, water was required at least once every 14 days to support growth of sedum growing in 2 cm of substrate, but could continue growing for 28 days at a 6 cm depth. Although the Sedum

Ancient green roof on a water cistern in India, City of Mandou. Source: M. Köhler.

vegetation was still viable after 88 days of drought, water should be applied at least once every 28 days for typical green roof substrates and more frequently for shallower substrates to sustain growth.

In a companion study, Durhman et al. (2006) compared growth, volumetric moisture content, plant stress (by measuring chlorophyll fluorescence), and ET of three drought tolerant CAM succulents *(Sedum acre, Sedum reflexum*, and *Sedum kamtschaticum ellacombianum*) to two non-CAM herbaceous perennials and grasses (*Coreopsis lanceolata* and *Schizachyrium scoparium*). The study was conducted in a substrate that was 7.5 cm deep and plants were subjected to the same watering regimens of 2, 7, 14, 28, or 88 days between watering. Initial volumetric moisture content after a watering event was as high as 0.34 m^3/m^3, but by day 5, there was no detectable substrate moisture except for those that received the 2 DBW treatment. For all species tested, receiving no water for six days resulted in lower ET rates (between 0.1 and 0.2 mm/day). The 7 DBW results contrast with VanWoert et al. (2005) where rates dropped to 0.0 mm/day for the *Sedum* mixture. This difference is likely due to differences in substrate depth as depths were much shallower in the VanWoert study. Substrates with *S. acre* and *S. reflexum* contained greater moisture under the 2 DBW regimen than those of *S. kamtschaticum ellacombianum*, *S. scoparium*, *C. lanceolata*, and the unvegetated control. This may be because these species spread along the surface and may have provided more shade, thus reducing evaporation from the substrate. *Schizachyrium scoparium* and *C. lanceolata* did not produce a dense canopy so there was minimal shading to reduce evaporation losses.

All of the *Sedum* spp. survived and maintained active photosynthetic metabolism to a greater extent than *Schizachyrium* and *Coreopsis*. Furthermore, when *Sedum* was watered after 28 days of drought, chlorophyll fluorescence values recovered to values characteristic of the 2 DBW treatment. In contrast, the non-CAM plants required watering every other day in order to survive and maintain active growth and development. One can assume that with frequent watering the non-CAM plants would remain photosynthetically active and continue to grow.

It is generally thought that by conserving water, drought tolerant CAM species such as Sedum may be inferior in terms of their ability to recharge a substrate for stormwater retention or for transpirational cooling. Given an adequate water supply through natural rainfall or supplemental irrigation, species with higher transpiration rates would remove more water from the substrate. However, this is not completely true as CAM plants do not necessarily conserve water when substrate moisture is abundant. Voyde et al (2010) quantified ET for *Sedum mexicanum* and *Disphyma australe* under increasing drought

Ornamental designed extensive Green roofs. Source: M. Köhler.

conditions and compared these values to bare substrate. Water loss from transpiration was rapid when plants had access to ample moisture and both species contributed nearly 50% of total ET. As the substrate began to dry out and the plants began conserving water, ET dropped and was not significantly different from the evaporation from the bare substrate. These findings challenge the assumption that CAM plants are always conserving water and thus not capable of recharging a substrate for water retention or for transpirational cooling. In addition, Voyde et al (2010) found differences in species. Daily peak ET was 0.29 mm/h for both species when water was available. Once water became limiting and the plants started to experience stress, peak ET for *D. australe* (0.05 mm/h) was approximately twice as much as *S. mexicanum* (0.02 mm/h), indicating that the sedum was better adapted for minimizing water loss.

In addition to stormwater retention, ET is also an important factor in cooling a roof and transpiration alone has been credited with up to 30% of roof cooling (Takakura et al., 2000). Thus it is easy to see the potential of green roofs for saving energy. Because the substrate acts as an insulation layer combined with shading from the plant canopy and ET, green roofs can reduce summer air temperatures just above a green roof as well as indoor temperatures under the roof. Of course, heat flux depends any many factors such as media composition, depth, and moisture content; plant species, supplementary irrigation, and local climate, building type, and construction details. As long as the substrate is not completely dry, there will be some ET taking place. This has practical applications in that providing adequate moisture is a cost effective method of cooling a building. Sun et al. (2014) conducted a cost-benefit analysis in Beijing comparing the cost of irrigation to that of the energy saved due to a lower air-conditioning (AC) requirement when a green roof has adequate moisture and reported that the costs of irrigating were lower than the costs to operate an air conditioner on an unirrigated green roof. Therefore, irrigating green roofs is a potential strategy for improving building energy efficiency in a temperate climate.

5. IRRIGATION

Although there is sentiment against irrigating green roofs for sustainability reasons, there are also many viable reasons why irrigation should be an option. As mentioned earlier, ET is an important factor in cooling a roof and can reduce energy requirements for cooling an individual building. At least in temperate climates, Sun et al. (2014) reported that irrigating green roofs was actually a more cost effective cooling strategy than operating air conditioners. In addition, for plants to function as intended, they need to have adequate water to avoid stress, remain healthy, grow, transpire, and remain aesthetically pleasing. Regarding stormwater retention, a balance must be found between providing enough water to maintain plant health while allowing the substrate to dry out enough to provide stormwater storage capability for the next rain event. The presence of plants reduces stormwater runoff due to transpiration and the fact that rainwater will be intercepted by foliage and may evaporate before reaching the substrate surface. In most cases, more plant biomass will result in greater transpirational losses and interception of rainfall. In addition, irrigation can increase biodiversity by allowing a greater selection of plant material for both extensive and intensive garden roofs.

It is also advisable to have at least temporary irrigation available when a green roof is first installed. This need depends on climate and time of year, but is usually necessary for summer installs, especially for cuttings and seeds that may dry out before they root. Initial irrigation will be required immediately after planting and the frequency of watering during the first few weeks of establishment will depend on temperature, irradiance levels, and the amount of rainfall. Thereafter, vegetation can be slowly weaned off irrigation.

The need to provide long-term irrigation depends on climate, plant selection, substrate composition and depth, and desired aesthetic quality. One must keep in mind that healthy plants are required for a green roof to function for its designed purpose.

Furthermore, there is a major international movement to use plants other than succulents such as native herbaceous perennials, grasses, and vegetable gardens on green roofs. However, unless substrate depths can be increased, these plants require supplemental water to survive and remain aesthetically pleasing on a roof and irrigation is a must if one desires to grow vegetables. The inclusion of irrigation also provides an opportunity for more biodiversity in plant selection. Increasing substrate depth can alleviate some of these problems, but shallow depths are often desirable because buildings must be structurally strong enough to support the added weight of the green roof.

If irrigation is to be used then two questions must be answered. What is the source of the irrigation water and what method of irrigation is best for the given roof? It could easily be argued that using potable water for irrigation is not sustainable, especially in areas where water is scarce. Collecting runoff and recycling it back to the roof is one solution and in doing so there would not be a strain on the municipal water system. However, during drought periods this water reserve may be depleted in times of need. There is also the possibility that continually recycled water may have an increased concentration of salts or other pollutants that could be detrimental to plant growth. Most people would probably be more amenable to using potable water if it was used only to supplement recycled water when required. Regardless of water source, the other question is what is the most efficient method of irrigation? Is it done manually with a hose or with an automated overhead, drip, or sub-irrigation systems. Which is the most efficient?

To answer these questions a study was conducted at Michigan State University to determine if irrigation method and physical properties of various substrates and systems influenced water distribution and retention and to quantify plant growth and health when subjected to different irrigation methods (Rowe et al., 2014).

In the first phase of the study, five commercial substrate types or systems were subjected to three irrigation methods (overhead, drip, and sub-irrigation) to determine substrate water distribution and retention. Measurements included volume of runoff (wasted water), substrate volumetric moisture content, and water dispersal (distance surface water front moves horizontally from emitter). Substrates subjected to overhead irrigation or those with a moisture retention fabric retained the greatest amount of water. Sub-irrigation resulted in the least amount of water retention and the most wastewater, except when a moisture retention fabric was present. Substrate volumetric moisture content exhibited similar results. The moisture retention fabric was effective in retaining water, but for sub-irrigation a visible water front was not visible as water did not reach the surface via capillary action. Differences can be attributed to the fact that overhead irrigation distributed water over 100% of the area, whereas in many cases the water front radiating from the drip or sub emitters never merged leaving dry areas in between emitters.

In Phase II these irrigation methods were assessed to see how they influenced plant growth and health of *Sedum album* and *Sedum floriferum*. Repeated measurements were recorded for plant survival, growth index, chlorophyll fluorescence, and substrate volumetric moisture content. Results show that overhead was the most favorable for plant growth and health and Sedum album exhibited over the twice the growth when subjected to overhead irrigation compared to sub-irrigation. However, the inclusion of moisture retention fabric generally improved results for drip and sub-irrigated plants. Chlorophyll fluorescence values were generally highest for plants subjected to overhead irrigation.

In this study, overhead irrigation outperformed both drip and sub-irrigation. The fact that there was little capillary movement of water through the coarse substrate from the drip and sub-irrigation emitters explains their poor performance. This is especially a problem for shallow extensive roofs which consist of primarily groundcovers. On deeper intensive green roofs, drip irrigation may be more practical for irrigating individual plants such as trees, shrubs, or vegetables. Overhead, drip, and sub-irrigation all have their advantages, but if irrigation is to be used then one must choose the most cost effective and environmentally friendly method of irrigation.

The efficiency of drip and sub-irrigation systems could be manipulated by blending finer substrates to increase capillary action, by altering the irrigation schedule, increasing the number of emitters and delivery lines, or using emitters with lower flow rates, but these changes may increase costs and could result in the substrate being too wet. Also, on a windy day, water applied from overhead systems may not reach the desired target. In addition, drip and sub-irrigation are less likely to be effective when establishing a roof. In this study plant root systems were initially within the original size of the plugs. On an established roof with mature plants, root systems would likely be deeper and exploit the entire substrate volume, and thus have greater access to water supplied by drip and sub-irrigation systems.

6. CONCLUSIONS

Water management factors such as plant selection, plant canopy cover, transpiration rates, substrate composition and depth, roof

El Cuartel de Ballajá it houses several educational and cultural organizations, with a wetland greenroof overhead with greenwalls and solar panels. Source: Greenroofs.com; Photo Courtesy of and ©rooflite®, Skyland USA.

A living wall – Geofelt - test installation in Frankfurt, Germany. Source: M. Köhler.

slope and orientation, climate, microclimate, and irrigation practices will all influence water retention, evapotranspiration, heat flux, and how well a green roof functions. These factors can be managed somewhat to maximize ecosystem services based on the original goals for the roof.

Growing substrates play a critical role in water management and water retention can be manipulated by altering substrate components and by changing depth. The ideal substrate must be able to sustain plant life while providing for the physical, chemical, and biological needs of the plants, be lightweight enough to stay within the load bearing capacity of the building, possess adequate water and nutrient holding capacity, be course enough to allow for drainage while not leaching pollutants in the runoff, not break down over time, and be sourced from locally available materials. Regardless of the materials used to formulate a green roof substrate, the finished substrate should fall within the FLL standards for green roofs.

The success of a green roof in terms of stormwater management is a function of how well a roof retains stormwater. This includes water that is held in the substrate, transpired through the plants, and evaporation from the substrate surface. Likewise, the ability of a green roof to alter heat flux and save energy also depends on substrate moisture (moisture changes the insulation capabilities of the substrate) as well as evapotranspiration from the plants and the substrate. Both stormwater retention and energy savings are also highly dependent on ambient temperature, humidity, and irradiance levels which influence evapotranspiration. It is generally thought that by conserving water, drought tolerant CAM species may be inferior in terms of their ability to recharge a substrate for stormwater retention or for transpirational cooling. However, many CAM plants experience rapid transpiration when water is available and only shut down during drought conditions.

Despite the benefits of reasonable irrigation practices, there is a concerted movement to limit irrigation on green roofs to drip or sub-irrigation or ban irrigation altogether. Banning or limiting irrigation on all roofs is problematic. Also, banning overhead irrigation in favor of drip or sub-irrigation because of perceived water conservation, regardless of the source, may be shortsighted and actually result in wasting water. Because coarse aggregates are often the main component of green roof substrates to allow for adequate drainage in shallow depths, and depths are shallow, there is less water holding capacity and little if any capillary movement of water. Therefore, water does not move laterally to a great extent as it would in finer substrates. For this reason, there are challenges to utilizing drip and sub-irrigation despite the increasing trend to specify these for green roofs. Overhead, drip, and sub-irrigation all have their advantages, but if irrigation is to be used then one must choose the most cost effective and environmentally friendly method of irrigation.

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CHAPTER 15

GREEN ROOF ENERGETICS: SYSTEMATIC ORGANIZATION AND INTEGRATION OF KNOWLEDGE

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ABSTRACT

Study of green-roof energetics improves understanding of thermal-energy processes to achieve more ambient and indoor cooling in summer and indoor warming in winter. The holistic green-building roof system offers an integrated research entity. Matter and energy flow amongst four compartments, namely ambient-air, green-roof, building-roof, and indoor-air, defines the conceptual framework. Thermal defence is evaluated by active evapotranspiration cooling and passive warming avoidance mechanisms, including subsurface cooling and abiotic-biotic thermal insulation. Theoretical and empirical findings are translated into practical hints to optimize energy effectiveness with respect to reducing heat gain, increasing heat loss, increasing thermal resistance, and increasing thermal mass effects.

KEY WORDS

Holistic green-building roof system, thermal mass, thermal defence, thermal inertia, thermal lag, ambient cooling, indoor cooling, subsurface cooling, indoor warming, warming avoidance.

1. INTRODUCTION

The benefits of green roofs have been emphasized in recent research endeavours. Half of humanity is now living in cities, and the proportion continues to rise without respite. It is imperative to find solutions to grave environmental problems that are generated in urban areas with major impacts on urban inhabitants. The urban heat island (UHI) effect, climate change, air and water pollution, crowdedness, lack of green spaces and divorce from nature have degraded quality of life in cities. Human societies are expected to find solutions to these vexing and chronic problems. It is essential to make cities climate-resilient and climate-proof to meet the pending and monumental challenges.

This study focuses on the provision of a special kind of urban green space (UGS), green roof, as a means to ameliorate urban harshness and stresses. Green roofs offer a new and innovative dimension to increase UGS and supplement its deficiency at the ground level especially in compact cities. Of the multiple environmental, ecological, social and economic benefits, energy effectiveness is of critical concern and has attracted wide attention in research and applications. To understand the relevant issues in depth, the design and material of the green roof could be evaluated in intimate association with the building roof. The two entities are closely coupled in delivering the resultant thermal-energy performance in indoor and outdoor milieus. It is necessary to study their synergistic contributions as an integrated system. The embodied energy of green roofs lies outside the purview of this paper.

Buildings consume a substantial proportion of energy used in cities in the heating, ventilation and air-conditioning (HVAC) service package. Energy savings due to green roofs can trim the energy bill, and bring various collateral upstream and downstream environmental benefits. Vegetated roofs can reduce air-conditioning energy use in summer and indoor-warming energy in winter. Widespread green-roof installation can lower city-wide ambient temperature to ameliorate the UHI effect and to offset the impacts of global warming. Secondary environmental benefits include suppression of smog formation, removing gaseous and particulate air pollutants, reducing overall quantity and peak of stormwater discharge, improving stormwater quality, and corollary far-reaching economic, social and health advantages.

As a relatively new and interdisciplinary knowledge realm, the concepts and associated terminology of green-roof science are in a state of flux and fuzziness. After some decades of development and applications, it is an opportune time to propose a standardized set of terminology in relation to energetics and cognate fields to facilitate communication amongst researchers and practitioners. The proposed terms are shown in italics.

Green roofs and PV-systems, both systems perform perfect together. Source: M. Köhler.

▲ Norwegian neighborhood" was estimated 1940 in Hamburg, most of these roofs are perfect until today. Source: M. Köhler.

2. NOTABLE GREEN-ROOF THERMAL-ENERGY BENEFITS

2.1 Diversities of findings generated by recent studies

Based on recent research findings on green-roof energetics, the following general thermal benefits can be condensed. They rely on two principal research approaches, namely modelling and simulation, and empirical experimental or monitoring studies. The results tend to vary considerably or even diverge mainly due to differences in underlying assumptions, evaluated parameters, computation methods, measurement techniques, measurement positions, climatic zones, seasons, weather conditions, urban morphology of study site and environs (elevation, building geometry, height and density), green roof materials and design, vegetation type (species, growth form, coverage, height, density, leaf area index, transpiration rate, and photosynthetic physiology), and irrigation regime. Attempts to generalize the findings and apply to a certain site could take into account the inherent variabilities. Future studies could clearly specify such fundamental factors to facilitate communication and scientific advancement.

2.2 Summer cooling effect

In comparison with bare (control) roof, green roofs in the warm season can lower temperature in two main ways, namely cooling of its own materials and adjoining outdoor air, and reducing heat ingress into indoor space (Spala, 2008; Spolek, 2008; Teemusk and Mander, 2009; Theodosiou, 2013). They can cool soil surface, leaf surface, and proximal air (lying close to the vegetation surface from 0–50 cm). The subsurface temperature in the soil, drainage, base (bottom of green-roof) layers can also be reduced. In turn, the building roof slab can be cooled to induce cooler indoor space. Besides, the diurnal temperature amplitude of material layers, adjacent outdoor air and indoor air can be compressed. Daily peak temperature is lowered and postponed. The maximum indoor diurnal cooling can range from less than one to several degrees Centigrade.

The cooling effects of a cluster of spatially-proximal elevated green spaces (green roofs and green walls), in conjunction with nearby ground-level green spaces, can coalesce to bring wider impacts. At the neighbourhood scale, the cooling effect of green roofs can spill to ground level to improve local microclimate. Vertical and lateral advection of cooled air is facilitated by low building height and small building footprint in relation to land area (Peng and Jim, 2013). In the cooled areas, the duration of high heat stress can be reduced to improve human thermal comfort, and UHI effect can be mitigated. More installation of green roofs across a city can induce spatial spread of cooling to the city scale and suppress UHI effect. A simulation study in Toronto found that 5% roof greening could lower mean temperature of the city up to 0.5°C, and application of irrigation could increase it to 1–2°C (Bass et al., 2002).

2.3 Summer warming effect

In contrast, the anomalous summer warming effect has been found due to establishment of the *green-roof heat-sink effect* (GHE) in humid-tropical area (Jim, 2014). On summer sunny day, absorption and storage of solar heat in extensive green roofs can trigger heat influx into indoor space, with some heat ingress in daytime but more in nighttime. The moisture content of green roof has increased its specific heat capacity and thermal mass effect (Section 4.1) to create a thermal gradient, pushing heat downwards to indoor space. Sufficient heat can be acquired in daytime to continue to push heat into indoor space after sunset. On summer cloudy and rainy days, the indoor space is relatively cool, whereas the green roof keeps its stored heat and remains rather warm. As a result, a notable amount of heat can flux into indoor space in both daytime and nighttime.

This some what unexpected summer heat intrusion and indoor warming due to an aberrant thermal behaviour of green roof can counteract, suppress or nullify evapotranspiration and subsurface cooling effects (Sections 5.4 and 5.5). It can raise the cooling load and lead to more energy consumption in air-conditioning. Contrary to findings outside the tropics, the tropical extensive green roof can fail to bring net cooling benefit to indoor environment.

2.4 Winter warming and cooling effects

In winter, green roofs can provide additional thermal insulation to reduce the loss of indoor heat through the roof. In cold climate, indoor space that is artificially heated can benefit from this energy conservation process to maintain *indoor warming* (Liu and Minor, 2005; Teemusk and Mander, 2010). In the subtropics, artificial heating is rarely practised in winter. The green roof cools down more than indoor space to generate a reverse or negative thermal gradient. Heat is lost through the green roof to induce a small *heating load* to indoor space (Jim and Tsang, 2011a; Theodosiou et al., 2013).

In subtropical areas, winter can be rather cool but indoor heating is seldom adopted. Bare roof can allow notable heat loss through the roof to induce uncomfortably cold indoor environment. However, on winter sunny days that are not too cold, solar radiation can warm extensive green roofs to build up sensible heat storage and generate GHE. The warmer green roof materials vis-à-vis a cooler indoor ceiling creates a thermal gradient to drive heat ingress to induce *indoor warming* (Jim, in press). The winter warming effect brought by tropical extensive green roof has implications on climate-change adaptation and indoor-heating consumption especially for an ageing population.

Casa Feliz Studios, in San Jose, CA. Source: Greenroofs.com; Photo Courtesy: Tremco Roofing and Building Maintenance.

3. GREEN-ROOF ORGANIZATION IN RELATION TO ENERGETICS

3.1 *Holistic green-building roof* (GBR) *system*

The modern green roof is composed of multiple contiguous layers of different materials with diverse thermal properties and behaviours. The materials are porous and permeable from top to bottom, allowing water to infiltrate and drain by gravity and air to move in or out of the system. To understand green-roof energetics, it is necessary to assess the intimate and dynamic interactions of the two major compartments, namely green-roof which is laid on building-roof. The *holistic green-building roof* (GBR) *system* includes these two solid compartments, sandwiched by two air compartments, namely ambient-air above and indoor-air below. The flow of matter and energy between natural-cum-artificial compartments and constituent components defines green-roof energetics. They operate jointly as a unified system and deserve to be evaluated as an integrated entity in thermal-energy performance studies. The thermal-relevant constituents of GBR system are summarized in Table 1.

3.2 *Green-roof compartment* and constituent layers

The *green-roof compartment* is commonly composed of six *green-roof layers* from the top downwards, namely vegetation, growing medium (or substrate), water reservoir (optional), filter, drainage, and root barrier. Some systems omit the water reservoir, and some systems place it between drainage and root barrier. The growing medium is usually a mineral soil enriched with organic matter to emulate a natural soil. It could include light-weight mineral or organic materials to reduce the total system load. The porosity provides spaces to hold air or water, to permit aeration, drainage, and

TABLE 1. THERMAL-RELEVANT CONSTITUENTS OF MULTIPLE LAYERS IN THE GREEN-BUILDING ROOF (GBR) SYSTEM

GBR LAYER	THERMAL-RELEVANT CONSTITUENT			
	CONSTITUENT AIR	CONSTITUENT WATER	CONSTITUENT WATER VAPOUR	THERMAL MASS
(A) GREEN ROOF COMPARTMENT				
Vegetation	H	L	H	L[a]
Soil	L to H[b]	L to H[b]	L	H
Water reservoir	L to H[b]	L to H[b]	L	H
Filter	L	L	L	L
Drainage	H	Lc	L	L
Root barrier	N[d]	N[d]	N[d]	L
(B) BUILDING ROOF COMPARTMENT				
Roof insulation	H	N[d]	N[d]	H[e]
Waterproofing	N[d]	N[d]	N[d]	L
Roof slab	N[d]	N[d]	N[d]	H

a The thermal mass of simple herbaceous vegetation of extensive green roofs is normally low.
b The amount of air and liquid water held in the pores is complementary, ranging from low level to 100%.
c Depending on design, the drainage layer can provide highly variable water storage capacity.
d N stands for nil to negligible.
e The roof insulation layer is usually accompanied by screed layer below and sand-cement bedding and roof tile above to increase it thermal mass.

water-holding capacity, and to facilitate root penetration. A water reservoir increases water supply using a relatively light-weight material, usually rockwool made of silica fibres with a high porosity. The energy state (suction) at which water is held is inversely proportional to pore size. Water in macro-pores (> 60 μm) in the growing medium and water reservoir is held at relatively low energy state, and it can be drained by gravity to reach the drainage layer (Jim and Peng, 2012b). Thereafter, it flows laterally on the building-roof surface with a fall of about 2% to be drained away from the roof as stormwater discharge.

The green roof layers, especially the growing medium and water reservoir, increase the thermal mass of the GBR system (Section 4.1). The increase can modify the system's thermal behaviour, such as thermal capacity and thermal inertia. The throughput of water under gravitational pull allows warmed water to move from growing medium to drainage layer to provide a heat-export pathway. If the infiltration capacity is exceeded, water can pond on the surface as temporary surface detention, the surplus of which can flow away as surface runoff to export heat.

3.3 *Building-roof compartment* and constituent layers

The *building-roof compartment* adopts different designs and materials, commonly including from the top downwards six *building-roof layers*: surface tile, sand-cement bedding, thermal insulation, waterproofing membrane, screed, and reinforced concrete slab. The sequence of their installation and recommended materials may vary in different jurisdictions. Water can penetrate the layers above the waterproofing membrane to enhance thermal capacity, inertia and conductivity (Table 1). The juxtaposition of the green-roof compartment on the building roof compartment creates a multiplex compound make-up composed of 12 material layers and 13 material interfaces, beginning with ambient air and vegetation, and ending with indoor air.

3.4 *Ambient-air and indoor-air compartments* and constituent layers

The two adjoining air compartments can form air layers due to micro-meteorological processes. The *ambient-air compartment* above the green roof includes 200 cm of so of near-ground air above the vegetation surface, which can be loosely stratified into the lower *proximal layer*, and the upper *distal layer*. The boundary height between the two layers may vary according to micro-meteorological condition near the ground. The proximal layer is more influenced from below by the green-roof compartment, especially by latent and convective heat fluxes. Depending on the temperatures of the green-roof surface and proximal air, hence the temperature gradient, the proximal layer can be cooled or warmed by the green-roof compartment. The proximal layer can sometimes be cooled to a temperature lower than the distal layer to create a *temperature inversion* (Jim, 2012). The distal layer is more influenced by general atmospheric conditions. Below the building roof, the *indoor-air compartment* may also be stratified into the *ceiling layer* and *floor layer*, due to temperature difference and hence density of air in the relatively stable interior environment.

A parc-connector system above a Bus station in Hong Kong. Source: M. Köhler.

4. PERTINENT CONCEPTS IN GREEN-ROOF ENERGETICS

4.1 *Thermal mass* and ancillary effects on green roof

Adding new green-roof layers increases the total thickness of the GBR system, hence its *thermal mass effect* (Table 1). The highly efficient thermal mass effect is exemplified by old masonry buildings with massive walls. Thermal mass is a material that can soak up heat, akin to a sponge soaking up water (Al-Homoud, 2005). It slows down the thermal response time to solar irradiation. The efficacy of the thermal mass effect is contingent on its density, not its volume. High-density building materials such as stone, concrete, gypsum and adobe (compacted soil) have higher specific heat capacity to serve as effective thermal mass (Gregory et al., 2008).

Heat absorbed by thermal mass creates an *energetic liability*, to be passed on to the side of the material with lower temperature. The heat is stored temporarily, and it has to be released to the environs, indoor or outdoor, depending on the temperature difference between it and the environs, and temperature gradient.

A GBR system with a high thermal mass takes some time to absorb heat on the outside surface, and warm up gradually in daytime. It takes time for heat to conduct through its thickness to the other side (indoor side). The appreciable amount of stored heat is released gradually in both directions (indoor and outdoor) whilst it remains warmer than outdoor and indoor air after sunset and in nighttime. Thus thermal mass can generate the *time delay* or *thermal lag* phenomenon, postponing the heat ingress and dampening temperature fluctuation of the thermal mass itself and the indoor space.

Green roofs and PV-systems, both systems perform perfect together. Source: M. Köhler.

Thermal lag can usher energy benefits in an indirect manner. For instance, in a diurnal cycle, it may take about five hours for the outdoor peak temperature to express as indoor peak temperature on a hot summer sunny day (Jim, 2014). It implies that the indoor peak cooling load occurs five hours after the outdoor peak temperature, at which time the outside air temperature would have dropped to a relatively lower value in comparison with the earlier outdoor peak. The cooler evening allows the air-conditioner to operate more efficiently (use less energy) to cool the air to the thermostat level. The peak load on the cooling equipment is also lowered, thus a smaller and less costly machine can be used. Overall, savings on electricity charges and equipment purchase could be achieved. The thermal lag does not reduce the total amount of heat flux into the building. It postpones the peak flow to a time that can provide energy saving by the cooling equipment.

Green roof can also induce *thermal inertia*, which is the ability of thermal mass to dampen diurnal temperature fluctuation, keeping it within a limited range which is notably narrower than the ambient diurnal temperature range. Ambient temperature tends to oscillate quite widely within a day, especially on a hot sunny summer day. The thermal mass provided by green roof in tandem with building roof can suppress temperature fluctuation in the GBR system. The amount of dampening tends to increase progressively with depth in green-roof layers (Jim, 2014). Upon reaching indoor air, the diurnal temperature range is shrunk to only a few degrees Centigrade.

For instance, in a diurnal cycle, the peak latent heat (λE) and sensible heat (H) fluxes occur at 1200–1300 h, but soil heat flux (G) peaks later at 1400–1500 h, indicating a time lag of about 2 h (Jim and He, 2010). At the base of the thermal mass and indoor space, the diurnal temperature amplitude can be compressed to only several degrees Centigrade even on a summer sunny day (Jim, 2014). By analyzing the ratio between green-roof heat storage and incident solar radiation, a one-day time lag is found in indoor warming after a hot summer sunny day (Tsang and Jim, 2011).

4.2 Bowen ratio and green-roof thermal performance

Heat flux partition in green roof tends to follow a sequence: Latent heat flux λE > Sensible heat flux H >> Soil heat flux G, with G usually insignificant. Considering the two main heat flux components, the Bowen ratio, $\beta = H/\lambda E$, presents a concise quantitative profile of heat-dissipation pathways of green roof. When $\beta = 1$, sensible heat loss and latent heat loss are the same. Dry areas have high β, and wet areas low β. The value decreases with precipitation until it drops down to 0.1 of open water body. It is inversely proportional to rainfall and soil moisture, and proportional to relative humidity and absolute surface net radiation (R_n). For comparison, a tropical rain forest in the wet season has $\beta = 0.17$, a desert has $\beta = 10$, and urban areas (built-up) typically has $\beta = 5$.

Green roof has limited sensible heat flux but it is dominated by latent heat transfer. The evapotranspiration component of green roof conforms to prediction by the Penman-Monteith equation (Rezael et al., 2005). With moist soil, it maintains a low β around 0.12–0.35, implying that λE is often 3–8 times of H (Gaffin et al., 2005, 2006). The value is comparable to a well-irrigated or moist agricultural field in summer with $\beta = 0.20$–0.25. High β has pertinent implications on the green-roof energy budget. It indicates that a notable amount of heat staying in the green roof can induce convective heat transfer to warm ambient air. This warming process is the opposite of latent heat loss from green roof which can cool ambient air. In other words, if the sensible heat stored in the green roof is not dissipated by latent heat loss, it can be transferred to the ambient air by convection. Some of the stored (not dissipated by evapotranspiration) heat can be transferred downwards by conduction to reach indoor space.

Bare roof without latent heat dissipation can always store more heat than green roof, sustaining more sensible heat flux than vegetated roof to result in a high β (Jim and He, 2010; Tsang and Jim, 2011). Latent heat dissipation by tropical green roof is more efficient, about twice that of temperate region (Tsang and Jim, 2011). This can be explained by a combination of stronger solar irradiance and liberal availability of water. The β of green roof decreases with complexity of biomass structure and leaf area index, with control (bare) > turfgrass > groundcover herb > shrub (Jim and He, 2010). Low β is conducive to the formation of cooler and more humid microclimate in the proximal air layer.

4.3 Critical role of water in green-roof thermal performance

The green-roof growing medium has to be porous to provide a balanced and complementary supply of water and air to support plant growth. The total porosity of a well-structured soil occupies 50% or more of its volume. Water can also be held in the water reservoir layer to serve as an extension of the growing medium by providing supplementary water supply to plants. This stored water can move up by capillary rise to replenish the growing medium layer. Plant roots can also grow into the water reservoir layer to tap water directly. Part of the drainage water that enters the drainage layer is stored in its receptacles to be returned via capillary rise or vaporization followed by condensation in the pores of the growing medium and water reservoir. Soil moisture is regularly restocked by rainfall and irrigation, and released by gravity drainage and evapotranspiration.

The presence of water in green roof has important bearing on its thermal properties (Table 1). It plays multiple roles, including heat storage, cooling, warming, heat transfer, and heat export. Continual changes in soil moisture content can bring dynamic changes in thermal behaviours. The water sustains evapotranspiration which provides a key active cooling mechanism mainly for surface materials and ambient air (Section 5.4), and secondarily for indoor air via subsurface cooling (Section 5.5). Latent heat release of green roofs can range from 100–600 Wm^{-1}, depending on solar radiation inputs. Water works in tandem with solar radiation to drive this biotic cooling mechanism. Solar irradiance that would otherwise consumptively heat up dry building roof materials can be converted in green roof to productive use to bring cooling with the help of water.

Water has a high specific heat capacity, which is the amount of heat a material can hold, at 1.9 $kJkg^{-1}K$. In comparison, most building materials have 0.4 to 0.6 $kJkg^{-1}K$. Thus water can store an appreciable amount of heat energy but bringing limited rise in temperature. Water can significantly enhance the specific heat capacity of the thermal mass of the GBR system. Daily peak temperature can be depressed, and diurnal fluctuations in temperature can therefore be dampened. Water has a high thermal conductivity. The thermal conductivity of wet to moist soil can reach 0.5–0.6 $Wm^{-2}K$. Thus water in the growing medium and water reservoir layers can reduce the R-value and facilitate heat transfer by conductance.

After heavy or prolonged rainfall or ample irrigation, the pores can be saturated with water to provide maximum potentials to store and transmit heat. Plentiful input of water can absorb heat from green-roof layers and induce cooling. A saturated or wet soil has excellent hydraulic conductivity to facilitate water drainage and hence transfer of *embodied heat*. In other words, the hydraulic conductivity of wet soil can foster the development of *thermal continuity*. However, the pore water will soon be depleted by a combination of drainage, evaporation and root intake, thus gradually reducing thermal continuity. Water draining downwards through green roof layers can transfer heat from upper to lower layers. On a hot summer day, upper green-roof layers are usually warmer than lower ones, thus drainage can effect internal heat distribution. Water released from green roof as stormwater discharge or surface runoff can export heat (Section 5.5). Largely emptied pores have thermal properties dictated by air which is a good insulator but a poor conductor (Section 5.6; Table 1). The resulting *thermal discontinuity* of dry soil contrasts sharply with that of wet soil.

5. GREEN-ROOF AS THERMAL-ENERGY PROCESSOR

5.1 Building roof and thermal defence

Green roof offers a synergistic combination of biotic and abiotic materials, with diverse composition, properties and behaviours, to generate diverse ecological processes. Properly designed and managed, it presents an efficient processor of energy and matter to bring multiple and sustainable benefits. Green roof adds value to a conventional bare rooftop, which otherwise is a net contributor to cooling load of buildings. To understand the multiple thermal functions of green roof, we can begin with its basic bedding, the bare building roof, and explore how the addition of the green roof can substantially modify the energy budget of the roof site and affected indoor space.

The rooftop can be considered as a horizontal external wall of the building envelope that provides a shield against the capricious and sometimes harsh elements, mainly direct sunshine, hot and cold air, strong wind, and moisture. It is a first line of a building's defence to make the interior space habitable and comfortable. However, the thermal-insulation protection is often not too effective with reference to heat penetration into or escape from indoor space. The weakness in the defence line can be breached on both sides and hence can permit heat flow in both directions.

Integrated concepts with green infrastructure and modern materials. Source: M. Köhler.

5.2 Bare roof and breached thermal defence

A bare roof on a hot summer day can absorb an appreciable amount of solar radiation to raise temperature of the surface and interior of the building-roof thermal mass. The building-roof compartment is the hottest object relative to adjoining ones, sandwiched above by the cooler ambient-air compartment and below the cooler indoor-air compartment. Heat flows spontaneously along two *thermal gradients*, respectively upwards and downwards, to find equilibrium distribution (first law of thermodynamics). Convective heat flux transmits heat upwards from building-roof compartment to ambient-air compartment to cause *ambient warming*.

The stored heat in the building-roof compartment is also pushed downwards to permit notable heat ingress to extend beyond sunset, imposing *indoor warming* and a notable *cooling load* in daytime and evening (*heat-gain period*). However, heat can escape in nighttime until sunrise through the bare roof (*heat-loss period*). The *heat flow reversal* in a 24-hour cycle, alternating between heat gain and heat loss periods, can limit the *daily net heat flow* into indoor space. During the heat gain period, air-conditioning can be enlisted to shift indoor temperature to the comfort zone.

5.3 Augmented thermal defence by green roof

Green roof can augment a building's thermal defence, to reduce heat gain on hot days and heat loss on cold days, as well as heat gain in daytime and heat loss in nighttime. *The study of green-roof energetics can improve understanding of the warming-cooling mechanisms, and apply the knowledge to optimize green-roof design, so as to derive primarily more cooling benefits in summer and secondarily more warming benefits in winter.*

Expectation of cooling benefits has two facets, namely cooling of the ambient air above green roof (*ambient cooling*), and cooling of indoor air below it (*indoor cooling*). Expectation of warming benefits is normally confined to indoor warming in winter, by reducing the loss of artificially

Atlanta City Hall, the first municipal living roof in the southern U.S. Source: Greenroofs.com. Photo Courtesy of Bill Brigham.

generated heat from indoor space through the roof to the outside environment.

Installing a green roof literally adds a living veneer (green skin) to the non-living and rather lifeless and harsh building-roof compartment, drastically transforming it and giving a new lease of life to its energetic processes and functions. It overhauls the regulation of heat inflow, storage, conversion, internal flow and outflow in the GBR system (Table 2). Two modes of cooling can be identified, namely *passive indoor cooling and active ambient cooling*. Their realization is dependent on different factors and processes.

On a hot summer day, the thermal mass of the GBR system takes up heat in daytime to get hotter than the indoor-air compartment to generate a *positive thermal gradient*. Heat can be drawn into indoor space. The amount of heat ingress depends on the temperature difference between the GBR system and indoor-air compartment. In comparison with bare roof, green roof can suppress its material warming to reduce heat ingress into indoor space. The *warming suppression* can be achieved in five ways, respectively *active cooling* of evapotranspiration at surface (Section 5.4), and a package of *warming avoidance* mechanisms, including passive shading, rejection of incoming solar radiation, export of

TABLE 2. THE POSSIBLE THERMAL TRANSMITTANCE PATHWAYS THROUGH THE MULTIPLE LAYERS OF THE GREEN-BUILIDNG ROOF (GBR) SYSTEM

GBR LAYER	THERMAL TRANSMITTANCE PATHWAY[a]				
	CONDUCTION	CONVECTION VIA AIR MOLECULES[b]	CONVECTION VIA WATER MOLECULES[c]	LATENT HEAT TRANSFER VIA WATER VAPOUR[d]	RADIATION TO AMBIENCE
(A) GREEN ROOF COMPARTMENT					
Vegetation	√	√	√[e]	√	√
Soil	√	√	√	√	√
Water reservoir	√	X	√	X	X
Filter	√	X	√	X	X
Drainage	√	X	√	X	X
Root barrier	√	X	√[f]	X	X
(B) BUILDING ROOF COMPARTMENT					
Roof insulation	√	X	√[g]	X	X
Waterproofing	√	X	X	X	X
Roof slab	√	√	X	X	√[h]

a The symbol √ stands for normal thermal transmittance pathway, and X for no.
b Refers to heat transmittance to the ambience by transfer of air molecules .
c Refers to heat transmittance between green roof layers by water flow associated with infiltration or drainage.
d Refers to loss of heat from vegetation by transpiration and soil by evaporation and heat transfer to the ambience via water vapour.
e Heat can be tapped by liquid water from foliage or branch surface and transferred to soil surface by canopy drip or stem flow.
f The root barrier laid at the bottom of the green roof may permit some water to move through the gaps between over-lapping strips.
g If the waterproofing layer is laid below the roof insulation, it could be penetrated by water or water vapour.
h The lower surface of the roof slab is the indoor ceiling which can re-radiate far-infrared radiation to indoor space.

heat by longwave outgoing radiation, export of heat by drainage and surface runoff water flow, and export of heat by convective heat flow (Section 5.5), as well as thermal insulation (Section 5.6). Ambient cooling is mainly contributed by active cooling of evapotranspiration, whereas indoor cooling by a basket of warming avoidance mechanisms (Jim and Peng, 2012a).

5.4 Active surface and ambient cooling of green roof

Green roof achieves cooling through multiple mechanisms. The heat source of green roof is principally solar radiation, which performs different works under different roof circumstances. On bare roof, solar irradiance is converted to sensible heat to induce unidirectional warming of the building roof. On green roof, solar irradiance triggers dual and opposite warming and cooling of materials. They are realized in different ways. Incident solar radiation converted to sensible heat can warm up the surface of vegetation and soil. The same solar energy is used by green plants to fuel photosynthesis to produce food, and to propel transpiration to release water in vapour form mainly through stomata of leaves. It also sustains the physical process of evaporation from soil.

The portion of solar radiation consumed in photosynthesis cannot be used to cause warming. Thus photosynthesis contributes to cooling in an indirect manner. The portion used in evapotranspiration can drive the cooling process. This process is made possible because of the presence of water in the green-roof growing substrate. Solar radiation in conjunction with water brings cooling. The change of water phase from liquid to vapour, with the help of solar energy, consumes a significant amount of latent heat of vaporization. The heat is extracted from leaf tissues and soil to bring their cooling.

Cooling at green-roof surface can create a thermal gradient to draw heat upwards to be dissipate at the surface by the triple processes of evapotranspiration, convection and longwave outgoing radiation. The moisture content of substrate therefore plays a key role in the cooling effect (Koehler, 2004). Irrigation can keep soil moist to feed evapotranspiration and sustain latent heat uptake and cooling (Theodosiou et al., 2013). The water-holding capacity of the substrate can determine the amount of water available for evapotranspiration between rainfall or irrigation events. Soil with more meso-pores (0.2 to 60 μm diameter), which can hold water available for plant growth but not drained away by gravitation pull (held by the soil mineral matrix at a higher matric potential), is more conducive to sustaining evapotranspiration process (Jim and Peng, 2012b).

Thus the surface of green roof, composed of plant tissues and soil, is actively cooled by evapotranspiration in daytime by solar energy. Vegetation with active transpiration can cool effectively leaf surface and tissue temperature, which is usually kept below the ambient air temperature. The cooled surface can in turn cool the adjacent proximal air to induce ambient cooling. If more heat is taken away by evapotranspiration cooling, less heat is left in the GBR system to move downwards to warm indoor space.

5.5 Warming avoidance and subsurface cooling of green roof

Heat that has not been actively dissipated at the surface (Section 5.4) is accumulated in green roof layers as stored heat. It can be further dissipated via different pathways (Table 2) before it has the chance to reach the base of the GBR system, which is the indoor ceiling. It means that some of the stored heat can be intercepted on its journey to the indoor ceiling, and thus will not have the chance to flow into indoor space. The subsurface layers in the GBR system can be kept relatively cool by various *subsurface cooling* processes. The efficacy of these *warming avoidance* mechanisms can play a critical role in reducing indoor heat gain. Adding green roof offers shading, which can block solar radiation from reaching the building roof, presenting a highly effective gate-keeper to heat absorption by the building fabric.

Reducing incoming solar radiation and increasing outgoing terrestrial radiation offer means of energy interception. Green roof can passively avoid warming in daytime by reflecting incoming solar radiation (direct and diffuse) due to the relatively high albedo (reflectivity) of living vegetation (commonly A = 0.7–0.85). More near-infrared (NIR) radiation is reflected than photosynthetically-active radiation (PAR) (Jim and Tsang 2011b), adding a new dimension to the beneficial role of passive cooling by green roof. The warm green roof materials can actively lose heat by longwave (far infrared) radiation in both daytime and nighttime. Vegetation in general has high emissivity of $\varepsilon \geq 0.9$ to re-radiate efficiently.

Overall, vegetation is endowed by nature with high albedo as well as high emissivity, for highly efficient heat dissipation with the help of solar radiation. Green roofs, however, do not cool mainly by high albedo or high emissivity. They cool mainly by high latent heat loss which is driven by solar radiation. Heat in the green roof can also disperse by convective flow to ambient air. The air molecules adjacent to the warm green roof surface can be warmed and then move physically (mass transfer) away from the green roof to export heat. Heat can move both upwards or laterally along with the air flow.

The permeable-porous green roof allows liberal penetration of water. Relatively cool irrigation and rainwater can capture heat effectively from green roof materials. Whether in stationary form in pores or flowing through pores, heat can be picked up by water molecules. The high thermal capacity of water implies notable uptake and storage of heat in the liquid medium. The conveyance of water within and outside the green roof can take heat as a passenger. The substrate moisture can flow by gravity to the drainage layer, whereupon it exits the green roof and discharges into the stormwater drainage system. In this way, the embodied heat in the drainage water is literally and liberally exported from the system. In a similar fashion, water that flow away from the green-roof surface as surface runoff before it infiltrates into the soil can also export heat. When rainfall intensity or irrigation rate exceeds infiltration capacity of the soil, surface runoff can be triggered.

5.6 Thermal insulation of green-roof abiotic layers

After subsurface cooling (Section 5.5), the *residual heat* storage in the GBR system, can conduct downwards to indoor ceiling and transmit to indoor space by convection and longwave radiation. The heat intrusion or positive heat flux commonly occurs on hot summer day with a large amount of solar radiation input that cannot be offset by the warming avoidance mechanisms will flow downwards to warm indoor space. This heat flow is carried by conduction, the passage of which is subject to inherent constraints of the GBR system. The multiple layers of green roof and building roof (Section 3), akin to a blanket, enhance thermal insulation or barrier to heat transmittance to indoor space. Thermal insulation can reduce heat absorptivity and retard heat transmission through the material layers.

The temperature difference on two sides of a roof material layer provides a thermal gradient which is the driving force for conductive heat flow from the warmer side to the colder side. The rate of heat flow is regulated by thermal resistance (*R-value*), or its reciprocal parameter, thermal transmittance (*U-value*; U = 1/R). Both values are expressed in $Wm^{-2}K$ unit. Usually, the *steady-state R-value and U-value* is used, and its computation requires a constant difference in temperature across the material. An effective thermal insulator has high R-value and low U-value. The thickness of each layer can correspondingly increase its thermal resistance.

Cook+8th floor penthouse in Manhattan. Source: Greenroofs.com. Photo Courtesy of Green Roof Blocks.

Thermal insulation of the GBR system is the resultant of its multiple-layered materials and varied factors. For the green-roof compartment, it is provided by a combination of both living vegetation as well as the abiotic material layers (Del Barrio, 1998; Eumorfopoulou and Aravantinos, 1998; Lazzarin et al., 2005; Jim, 2012; Jim and Peng, 2012b). Stagnant or still air occluded within the green-roof compartment can serve as effective thermal insulator.

The highly porous growing medium and water reservoir layers are two-phase materials composed of minerals with intervening and connected pores. A non-compacted and well-structured soil normally has 50% (v/v) porosity, and a rockwool water reservoir material has 80%. The minerals and air-filled pores can retard heat transmission. Water-filled pores, however, can lower their R-value. Thus thermal insulation of these porous materials is a dynamic property that varies with their moisture content.

The drainage layer has ample internal spaces that are filled with air most of the time to create a *subsurface temperature discontinuity* (Jim, 2012), to constrain heat flow across it and thus provide an excellent thermal insulator (Jim and Tsang, 2011c). Moreover, the air inside the drainage layer is effectively trapped to restrict convective heat flow out of the green roof. Thus this synthetic layer plays a clinching role in reducing heat flow from green roof to building roof, and hence trimming the heat available for transmission to indoor space. The two thin layers made of synthetic materials, respectively the low-density geotextile filter above and high-density root barrier below the drainage layer, offer some thermal resistance.

The building-roof compartment has concrete and cement-cum-sand (bedding or screed) layers with thermal insulation of various magnitudes (Section 3). The thermal insulation layer has the highest R-value. The slightly porous layers lying above the waterproofing membrane can be penetrated by a small amount of moisture to reduce their R-value (Jelle, 2011). Moreover, high temperature in the material layers can in reduce their R-value (Al-Homoud, 2005).

For buildings especially old ones with poor thermal insulation, green roof can notably improve the aggregate thermal insulation of the GBR system. They can derive more indoor cooling benefit from green roof installation (Niachou et al., 2001; Castleton et al., 2010; Jaffal et al., 2012). Conversely, for buildings endowed with good thermal insulation, this added value is less significant. Such green roofs tend to bring mainly ambient cooling rather than indoor cooling.

Thermal insulation plays a contradictory service, akin to a double-edged sword that cuts both ways. It can reduce heat inflow into indoor space (usually occurring in daytime) and outflow from indoor space (usually occurring in nighttime). The diurnal heat-flow reversal (Section 5.2) can be suppressed if the thermal insulation is too effective. Thus nighttime heat release from indoor space is trimmed to impose a *thermal penalty*, increasing its diurnal net heat gain. Comparing with bare roof, on a hot summer day green roof usually offers cooler daytime but warmer nighttime in indoor space (Jim, 2012, 2014).

5.7 Thermal insulation of green-roof biotic layers

Temperature differences between vegetated and control roofs occurred mainly in daytime. Vegetated roofs bring lower daily maximum and minimum ambient air temperatures, but they do not cool better than control in nighttime. In daytime, control and grass surface temperatures are usually warmed above ambience, whereas groundcover herb and shrub followed ambience (Jim, 2012). Despite the more complex biomass structure, the semi-intensive shrub roof carries the most extreme diurnal temperature regime. Despite the simplest biomass structure, turfgrass can cool proximal air better than groundcover herb and shrub.

The vegetation biomass structure provides thermal insulation by trapping stagnant air in its canopy amongst branches and leaves (Eumorfopoulou and Aravantinos, 1998). The vegetation growth form is instrumental in determining its insulation effect. Simple turfgrass is less effective than herbaceous groundcover. Dense woody vegetation with high leaf area index and complex biomass structure, such as closely-planted shrubs or trees, can create a stagnant proximal air layer within the biomass structure and generate a *perched temperature discontinuity* to restrict heat flow through it (Jim, 2012). The still air on leaf surface (boundary layer) provides insulation effect. The intercellular space in leaves also serve as thermal insulator. The air layer adjacent to the soil surface similarly tends to remain rather stable to enhance insulation effectiveness.

For roof woodland, the complex biomass structure and thick soil offers notable thermal benefits (Jim and Tsang, 2011a, 2011b). Similar to extensive green roof, evapotranspiration is mainly influenced by intensity of solar radiation and relative humidity, but less by wind. The intensive green roof with densely-planted trees and 100 cm of soil provide excellent thermal performance to cool both outdoor and indoor air. The thick substrate with significant thermal mass operates as a highly effectively heat sink to dampen diurnal and seasonal temperature fluctuations. Only 10 cm soil thickness is found to be sufficient to reduce heat penetration into interior space through the green roof. For comparison, in a bare soil system, 90% of daily heat exchanges occur in the top 20 cm of soil (Pearlmutter and Rosenfeld, 2008).

The tree canopy in the sky woodland reduces solar radiation reaching the soil surface by shading and reflection, trimming it down to about 20% of incident solar radiation. The air trapped below tree canopy subdues convective heat loss and raises air temperature near the soil surface (Jim and Tsang, 2011a, 2011b). The cloistered subcanopy environment develops its own rather stable woodland microclimate. Convective and latent heat loss in the subcanopy domain is suppressed, and heat released from the soil could be trapped, thus reducing the passive cooling mechanism.

Overall, the tropical rooftop woodland is relatively less efficient in cooling ambient air than its temperate-latitude counterpart (Jim and Tsang, 2011a). Maximum transpiration occurs not in hot summer, but in early autumn when temperature remains relatively high but rainfall and relative humidity dropping to a low level. In winter, the warmer indoor environment vis-à-vis the cooler green roof draws heat upwards to increase the heating load of indoor space. This finding in the tropics contrasts with the results obtained in cold climate.

6. CONCLUSION

Based on a comprehensive review of the present state of knowledge on green-roof energetics, some practical measures could be distilled to improve green roof energy effectiveness and performance. The accumulated theoretical and empirical research findings can inform green-roof practice to modify or even overhaul the way green roof is designed and managed to optimize the energetic benefits. It is an opportune time to make use of progress in science to improve the environment and the community. The fundamental principle is to maximize nature's cooling and heat-defence mechanism of green roofs in different parts of the vegetation-soil-water complex. The review improves understand the key factors and processes of green-roof energetics, from which hints to enhance green roof design and management could be derived.

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CHAPTER 16

GREEN INFRASTRUCTURE PROJECTS IN AUSTRALIA

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ABSTRACT

A brief outline of the current development across Australia with examples of some projects ranging in size that represent major infrastructure initiatives, commercial and residential. It should be noted that at the time of publication there were limited resources and access to provide a comprehensive representation of the significant research in progress, all projects and policy changes due to mainly to time restraints and copyright release. Apologies, however further information about green infrastructure in Australia is available from the website: *www. GREENROOFSAUSTRALASIA.com.au*

KEY WORDS:

Australia, green infrastructure, buildings, environment.

1. INTRODUCTION

Global cities and towns are facing increasing population pressure, changing demographics and many environmental challenges, particularly related to climate change, water and food security. Critical to the health of people and communities is a deep engagement with green places.

In Australia 85% of the population resides in urban areas within 50 km of the coastline. The majority are located in Capital Cities which are all coastal. For Capital Cities going green requires a systemic approach which includes many alternatives such as reforming environmental education, providing a green infrastructure for urban environment, and conducting research and outreach community engagement. The four main areas of greening cities are grouped into categories of research, education, infrastructure and community. Of the four areas of practice with respect to delivering sustainability in Australian cities, building green infrastructure is on the top of Capital City sustainability agenda and currently is gaining the most attention. A sustainable city should have a healthy urban environment, with a prosperous economy through energy and resource conservation, waste reduction and an efficient environment management, and it should promote equity and social justice in its affairs and export these values at community, national and global levels. Cities are places where various activities can be connected with green initiatives to impact on the community and

Trio Apartements, Sydney. (Image courtesy Fifth Creek Studios).

society fundamentally. The connection between the educational mission and social role of city administration, particularly related to the physical environment, has been used as a rationale for city greening. The urban environment is a growing concern as data now supports the incidence of Urban Heat Island Effects, reduced air and water quality, reduced green space due to a rise in urban density, loss of urban habitat, unhealthy urban ecosystems, noise pollution and urban sprawl which also impacts on our innate human desire to connect with nature or biophylia.

Several projects and programs in education, research, outreach and stakeholder partnership have been in operation since the early 2004, sustainability initiatives in cities have only become significant since 2009. The most progressive Australian cities to embrace green strategies have been Melbourne, Sydney and Adelaide with targets to promote, implement and legislate programs such as the Melbourne "Growing Green Guide" with a strong collaboration in research with the University of Melbourne (Burnley Campus), street canopy planting; the City of Sydney "2030 Vision" which includes extensive street canopy planting and a "Green Roof Policy Guide-line"; the Botanic Gardens of Adelaide have a "Green Infrastructure Project" with research being conducted at the University of Adelaide, Uni of South Australia and Fifth Creek Studios (Graham Hopkins and Christine Goodwin).

Whether a city administration, State Government or Federal Government chooses to introduce or support sustainable green infrastructure to the Australian urban environment on a small or large scale, each decision has a fundamental impact on the society and industry, influencing the economic impact of local communities and citizens. As a result, greening a city is composed of many elements covering energy, water, waste, food, transportation, planning, building and implementation, all of which can contribute to sustainable urban ecosystems.

2. GREEN INFRASTRUCTURE PROJECTS

Green Infrastructure describes the network of natural landscapes assets which underpin the economic, socio-cultural and environmental functionality of our cities and towns – it is the green spaces and water systems which intersperse, connect and provide vital life support for humans and other species within our urban environments (Australian Institute of Landscapes Architects).

As a case study, some of the more significant green urban projects are described,

2.1. One Central Park, Sydney Australia

Two iconic residential towers rising above a retail centre, connected by terraced gardens to the main park beyond. World-class architecture, richly veiled in living green walls, 'One Central Park' encapsulates all that Central Park has to offer: bold, beautiful and globally significant new directions for 21st century living in Sydney as one of the world's most desirable cities to live.

Designed by award-winning Parisian architect Jean Nouvel with PTW Architects, One Central Park reminds us that nature can thrive in the city. Its façade is the canvas for a collection of breathtaking vertical gardens by French artist Patrick Blanc, delivering what architect Bertram Beissel describes as "a flower to each resident and a bouquet to the city".

This magnificent park is the new green heart of an inner Sydney district, home to a number of parks, vertical gardens and sculpture.

Central Park is a multi-stage $2 billion urban village, with a wonderfully diverse collection of residential opportunities arising in stages across 8-10 years while Central Park takes shape.

One Central Park is an awe-inspiring collaboration between French architect Jean Nouvel and French botanist Patrick Blanc, to create a Landscape which is architecture of continuity so the façades extend the park into the sky.

During first stage construction October 2013.

One Central Park is built around a beautiful, spacious park that will be the living heart of the new precinct. More than 30,000 sqm of parks and public spaces will welcome local communities into the heart of Central Park. Conceived by Denmark's Jeppe Aagaard Anderson and Sydney's Turf Design, the park will be framed by striking contemporary and heritage architecture.

The public park at the heart of the precinct climbs the side of the floor-to-ceiling glass towers to form a lush 21st century canopy. Like notes on a stave, the buds and blooms of the vegetation form a musical composition on the façade. The effect is a tree house retreat – a hi-tech bower. Vines and leafy foliage springing out of the between-floor planters and provide the perfect frame for panoramic views across one of the world's most beautiful cities to mountains and ocean. One Central Park offers Blanc a starry canvas of an entirely new scale using 250 species of Australian flowers and plants that change with the seasons and 200 exotic species. Blanc took inspiration from the vegetated sheer cliffs of the Blue Mountains west of Sydney.

This former Brewery Building will be incorporated as one of nine buildings to provide a strong connection to the urban fringe community of Chippendale. New open public parklands have created a gateway to Central Parks proposed marketplaces, cafes, restaurants & shopping complex which will integrate the existing heritage neighbourhoods with the projects 2000 new apartments, creating a socially unified urban village to be completed in stages over the next 8 years, at a cost of $2 billion.

Vertical Garden Installation.

2.2. Vertical Garden Installation & Maintenance

Gantries are being utilised for the vertical garden installation and future maintenance. Prefabricated steel brackets were bolted to slab edge anchors to provide a fixed vertical platform for prefabricated panels to attach providing a necessary air gap of 150mm between the building facade and the vegetated panels. The system, design & planting specs are provided by Patric - built off site, wrapped and delivered ready for fixing. These PVC panels have two 12mm layers of French non biodegradable synthetic felt matting, fixed by staples and chalk marked to create the specific design. The outer layer is slit for plant plugs to be inserted and then stapled to create a semi circular pocket. The roots extend between the two layers. Irrigation lines are wrapped in felt and fixed to the panels in ready for connection to main feeder lines onsite. The grey water nutrient enriched dripper irrigation system running across the wall at 3 metre intervals is automatically activated 6 times / day and also has remote control is a significant component to this adhoc hydroponic system. The longest vegetated panel on the East Tower is 250 metres x 5.2 m wide, north facing and subject to hot summer westerly breezes and salt laiden summer north easters.

The system has previously been trialled 5 km west at Camperdown on the Trio Apatements. Patric completed this 33m x 5m wall in 2009 using 4528 native Aust plants from 69 species.

A 36,000 litre water tank provides greywater for the irrigation. In 2011 it was left unactivated by mistake for 6 days until re-switched on. This coincided with hot weather and many plants died. However no other human errors have occurred since and the plants have maintained good health. The lower planting requiring more shade are Goodenia & Viola. The top level of plants being subject to more direct sun are Acacia & Poa. The plants were selected for their hardiness and tolerance due to a range of harsh climatic differences varying from salt laiden north easter winds in summer under high temperatures 26 - 35 deg C and strong winter southerly winds in mod temps of 13 - 17 deg C

The native plant palette has typical Australian characteristics of salt and drought tolerance under harsh summer temperatures. Just after these plants were settled Sydney experienced the hottest summer ever recorded with highs of 40 deg C. However they continue to establish. Established mosses were affected in the heat and some plants wilted however as with green roofs, green walls evolve with new species being introduced by birds, some thriving some not - which is why maintenance and regular monitoring is required over the initial two years. Plants closer to street level are subject to more shade and less wind and more carbon emissions from the major traffic artery. Of course plants at the highest levels being 350 metres are subject to extreme temps and wind loads.

The intent for an astounding tree house retreat or hi tec bower in the the heavens, Patrick has incorporated planters which will spill cascading creepers, vines and foliage swaying in the breeze with vines and creepers also ascending like green snakes up fixed stainless steel cables between floors. These plants will connect the massive vertical garden panels with horizontal bands hopefully creating a mad greeen patchwork tapestry rising from the parklands below at ground level. 250 native species including acaia, allocasuarina, carex, correa, dionalla, goodenia, grevillea, lomandra, poa, themeda and viola creating a veritable sky jungle. Plants were pre grown by Andreasons Nursery providing over 500,000 plants including 169 exotic species.

Trio Apartements, Sydney. (Image courtesy Fifth Creek Studios).

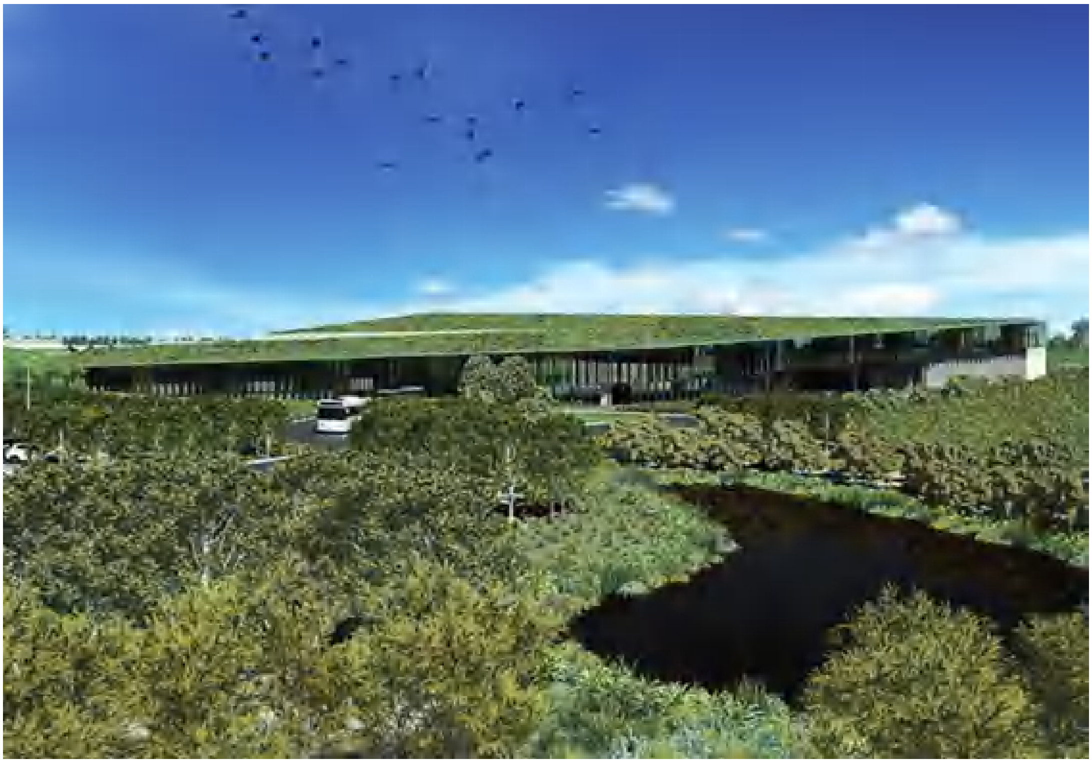
This project sets the bar high as a benchmark example on how we can green our cities and provide wellness benefits to the populations which reside in them.

Rather than standing alone as an inaccessible site OCP has opened its doors to the community through integrative planning and urban sensitivity which engages the city.

2.3 Victorian Desalination Plant, Wonthaggi, Victoria, Aus

The Victorian Desalination Project is set in an ecologically sensitive area on a 263 hectare site which will become a re-vegetated native parkland. The 2.7 hectare extensive green roof is part of the native parkland and was designed to ensure the reverse osmosis building has reduced visual impact, and integrates into its coastal context whilst providing insulation, stormwater and other environmental benefits to the building and its location. All plant species selected were provenance base selected and indigenous to the area. Around 110,000 tube stocks were used, made up of 25 species of ground covers, sedges, lillies and small shrubs. With a profile depth of 160mm from the waterproofing to the top of the stone mulch. The full saturated weight including mature plants is 139 kg/sqm.

Largest Public Private Partnership (PPP) project in the world $3.5 billion



PROJECT FACTS: The Victorian Desalination Project green roof is one of the largest in the southern hemisphere at 27,000 sqm.

Two shortlisted joint venture consortia

Aquasure (winner): SUEZ Environnement Degremont, Thiess Pty Ltd, and Macquarie Capital Group Limited;

BassWater: Veolia Water Australia Pty Ltd, John Holland Pty Ltd, and ABN AMRO Australia Pty Ltd.

Key design consultants for Aquasure

ASPECT Studios - Landscape Architects

Ashton Raggot and McDougal - Architects

Peckvonhartel - Architects

Parsons Brinckerhoff (PB) and Beca - Engineering Alliance

Green roof product & installation - Fytogreen Australia

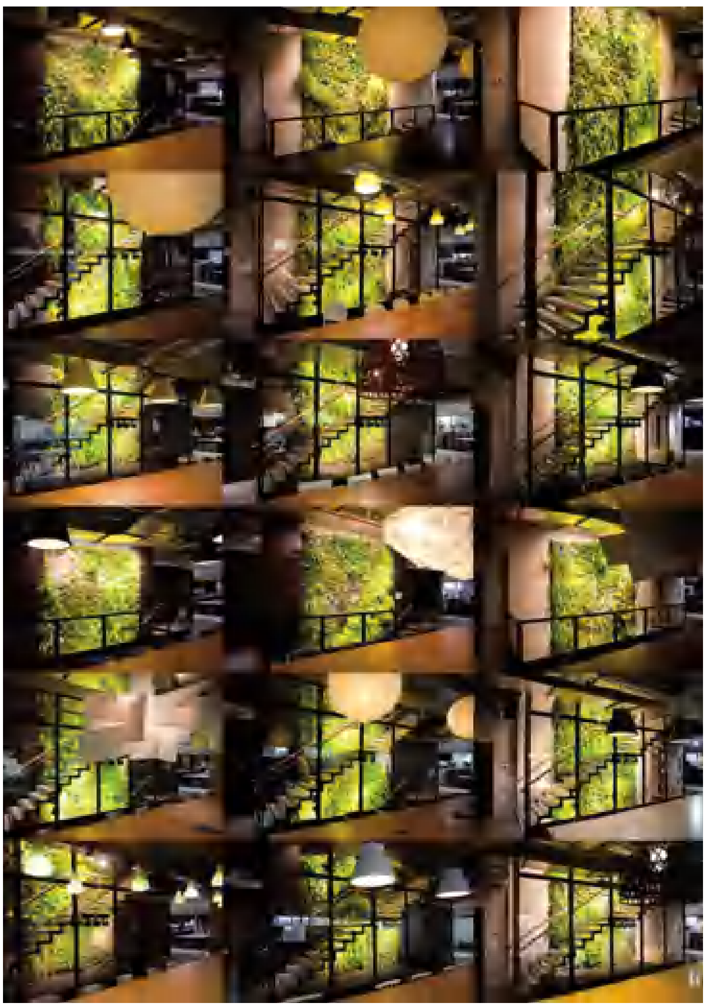
2.4 Largest green roof in Australia

One of the largest single ecological restoration projects (size 27,000 sqm) of its kind undertaken in Victoria,250 Ha of revegetation planting.

Environmental requirements relevant to the green roof: were visual amenity; social (including local industry participation); neighbourhood amenity; flora and fauna management; waterways and wetlands; water efficiency; energy efficiency; flooding control; surface water and groundwater management; site reinstatement and rehabilitation; noise and vibration management; coastal integrity.

The green roof integrates into the overall plant design and it is part of a significant public coastal park offering a high quality accessible open space experience including walking trails, wetlands, viewing decks, picnic areas, and a feature landscape experience.

Origin Energy Building. Continuous interior living wall - 22 levels.



Buildings and associated open spaces follow the natural topography.

The whole of the Leased Area was considered as part of the Process Plant site and integrated into the architectural and landscape design.

Any visual screening or sound attenuation components of the Desalination Plant were integrated into the overall architectural and landscape strategy for the Desalination Plant.

The Process Plant was treated as an integrated architectural composition in the landscape.

As the roof was to be visible from the middle and long distance was considered as a “fifth façade” and designed accordingly as a green roof.

Landscape design was integrated into the overall design of the entire Project with careful consideration given to the relationship between built form and open space.

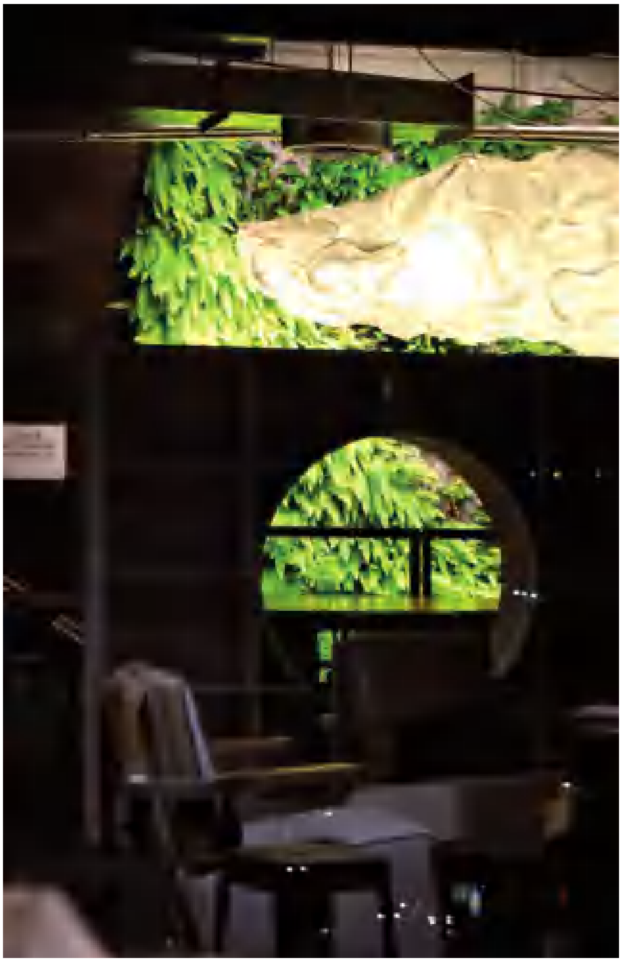
The scale of the landscape gestures is large and sweeping, commensurate with the scale of the Project and the landscape into which it is embedded.

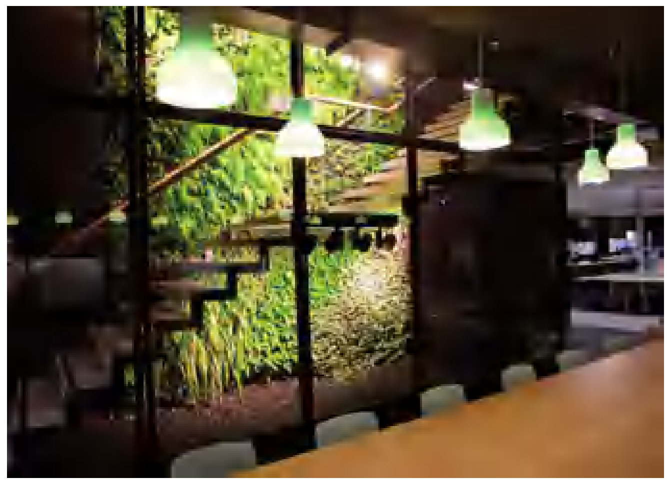
Origin Energy Building, Melbourne, Victoria, AUS

Australia’s first greenwall developer Mark Paul, Founder and Director of The Greenwall Company, has recently completed work on the tallest greenwall in the country. Spanning 22 floors of the Origin head office in Melbourne, each floor has its own unique planting make up, specifically designed to maximize varying angles and lighting.

Mark Paul, Horticulturist and Director of The Greenwall Company said, “They form a continuous green spine down the core of the building. A green lung and wild place to traverse while using the stairs between the floors.”

The Greenwall Company builds its walls from 94 per cent of recyclable materials that would





Origin Energy Building. Continuous interior living wall - 22 levels.

otherwise be destined for landfill, taking the benefits of their greenwalls beyond just their aesthetic appeal.

As well as providing an instant, textural green solution to architectural facades, additional benefits of a greenwall include thermal insulation, improved air quality, reduced noise and increased acoustics.

No. 1 Bligh Street, CBD Sydney, NSW, AUS. Living Wall

Size of project 377 sqm living wall @ 9.7-metres high & 40-metres long. Completed 2011

Design team and contractors: Design & Installation: Fytogreen Australia

Architect: Architectus + Ingenhoven. Builder: Grocon. Client: Dexus Property Group

Project drivers

(GBCA) 6 Star Green Star Rating. Demonstrate innovative green building practices.

Supply an entrance aesthetic in keeping with the building's design message.

Living Wall System: Fytogreen vertical garden system & proprietary growing medium. Features

No. 1 Bligh Street, CBD Sydney, NSW, AUS. Living Wall.

a series of modular panels containing a lightweight soil-less growing media, supported by a hydroponic watering system, computer control system with alarms via modems.

Plants: Philodendrons, ferns, lilies and groundcovers

Description: No.1 Bligh is the next generation in high performing sustainable office space, combining world-leading design, technology and sustainability in a premier location within Sydney's financial hub. It includes the largest vertical garden in Australia. The 10 m high green wall is made up of 11,000 plants and irrigated by the CBD's first black water recycling scheme generated from the Cbus tower & has a system of pumps incorporated into small cupboard rooms hidden as part of the green wall. The doors are almost invisible once they are closed. The plants are wild tropical water-loving plants. They are planted into boxes made up of geo-textile & filled with exceptionally light potting mix & polystyrene balls. These boxes are fixed to the wall & the plants planted into small cuts into the material. They naturally grow roots inside the potting material & some also on the exterior of the geo-textile itself.

The buildings atrium is the tallest in Australia & reaches the full height of the building (29 storeys) bringing fresh air to the upper levels. There is an internal 'winter garden,' plus an external 375-square metre terrace. A 700-square metre 'sky garden' crowns the building. The sky garden is shielded from the wind by a 10-metre glass wall. There are also numerous living internal landscaping features throughout the building.

2.5. Other green roof and living wall applications currently built or under construction in Australia

The major manufacturers for systems include Fytogreen Australia; Elmich Aus; Atlantis Corp; OzBreed; The Greenwall Company, Ronstan; Tensile Aus with waterproofing supplies by Sika; Sarnafil and what is becoming an industry standard International Leak Detectors (ILD) with many specialist installation companies. Examples of more projects from Melbourne and Sydney are shown below.

Barangaroo Headland Park, Sydney Harbour Foreshore Development, NSW, AUS

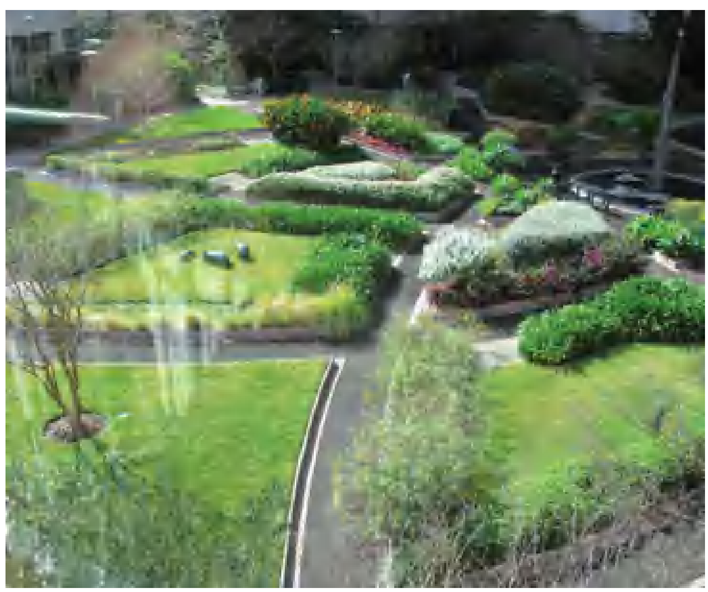
Barangaroo Headland Park, Sydney CBD foreshore is a Lendlease proposed development replacing container dock space with a public park. All proposed carparking and service buildings will be under an intensive green roof with eucalypt forests, cycle & pedestrian paths, recreational grassed areas and a connecting foreshore walk. (Artist impression by LendLease)

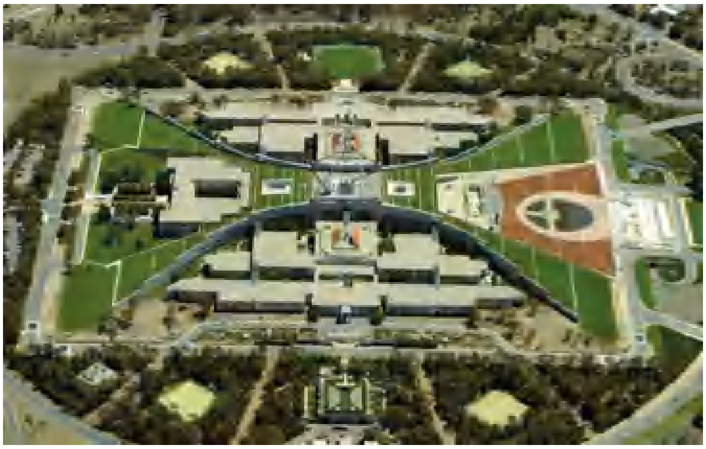
Darling Park, Sydney CBD, NSW, AUS

The largest inner city civic green roof park in the southern hemisphere ranges from intensive to extensive with a variety of native trees, shrubs, grasses and groundcover. The park is a retreat for city workers to enjoy the landscape, quite, bird-life and serenity.

▲ *Barangaroo Headland Park, Sydney Harbour Foreshore Development, NSW, AUS.*

▼ *Darling Park, Sydney CBD, NSW, AUS.*





▲ No. 1 Bligh Street, CBD Sydney, NSW, AUS. Living Wall.

▼ M Central Apartments, Sydney, NSW, AUS.

Australian Parliament House, Canberra, ACT, AUS

Architect: Romaldo Giurgola designed the green roof with the intention of replacing the natural form of Capital Hill which was excavated for the building. The soil was replaced over the roof structure and 40,000 sqm of turf was laid in 1987. It is one of the oldest green roofs in Australia and the only Parliament building in the world with a green roof. An image is celebrated on the Aus five dollar bill.

M Central Apartments, Sydney, NSW, AUS

Designed by 360 degrees Landscape Architects. The native landscape on the fourth level of this inner city development became the benchmark for providing habitat, improving biomass & insulation, noise attenuation, tenant amenity space and their pets. The project was the first in Australia to show that a well conceived green roof would improve the property value of the building.

Illura Apartements, Melbourne Victoria, AUS

Design and install by Fytogreen Australia. An example of supply and demand driven by real estae developments. Australian capital cities are moving towards increased urban density and developers have realised the benefits of living walls to exemplify green buildings and increase value and rental prices.

Illura Apartements,
Melbourne
Victoria, AUS.

La Perous
Residential,
NSW, AUS.

The Hills Clinic, Kellyville, Sydney, NSW, Aus.

PCA House, CBD Sydney.

Whatever the driver is, for more urban vegetation and a healthier urban ecosystem, it is welcome in Australia. "Green" has become an overused term but there can never be too many plants. Plants are the real Green.

La Perous Residential, NSW, AUS

Australian coastal species are salt and drought tolerant capable of surviving in low nutrient sandy media reducing the weight loading, installation, water and maintenance costs for a semi extensive green roof.

The Hills Clinic, Kellyville, Sydney, NSW, Aus

The Hills Clinic, Kellyville, Sydney, NSW, Aus. The living wall was installed to form a soothing environment and colourful entry for staff and patients. The project includes lighting, irrigation and drainage within the building. Overhead skylights supplement lighting and allow the large quantity of plants to provide oxygen and absorb toxins. (System: Atlantis GroWall4)

PCA House, CBD Sydney

PCA House, CBD Sydney. The living wall system was installed on a besser block wall in this new heritage office refurbishment. The vertical garden is seen from inside the foyer and by a number of design staff. The wall uses a number of colourful outdoor plant species for a spectacular array. (System: Atlantis GroWall 4).

3. CONCLUSIONS

With the demand for urban density, planners are aware of such environmental and social benefits and the obvious need to utilise the built form, using energy efficiency codes, sustainability and Water Sensitive Urban Design principles. The transition from grey to green is slow due to perceived costs and risks, skepticism about climate change impacts, lack of mandate policy and the instability of world financial systems, however the industry continues to grow driven by public demand, new research data and a growing awareness about the urgency to act sooner rather later. Australia is in a strong position to move quickly towards a green economy with a small population of 22 million and an abundance of natural beauty and resources.

ACKNOWLEDGEMENTS:

Botanic Gardens of Adelaide
Green Roofs Australasia Executives and Staff
Fifth Creek Studios - Graham hopkins / Christine Goodwin
360 Landscape Architects, Sydney
Fytogreen Australia
The Greenwall Company
Aspect Studios Melbourne
AtlantisCorp
Frasers Construction
Andreasons Green Nursery
City of Sydney
City of Melbourne
Habib & Ismaila, 2007
Alfieri, et al., 2009

The Terrace creates an inviting outdoor green space for Baltimore Convention Center guests above the exhibition halls and twenty feet above street level; it is estimated the new deck configuration will reduce energy losses through the structure by 35%. Source: Greenroofs.com; Photo Courtesy of Barrett Company. Para energy, landscape, green urban markets.

Toronto green terrace. Source: I. de Felipe.

AREA: AUSTRALIA

National organization:
Office: Green Roofs Australasia Ltd
22 Oxford Street, Sydney, NSW, Aus.
e-mail: info@GRaus.com.au

STRUCTURE AND MISSION:

Green Roofs Australasia (GRA) is a member based peak body for promotion, dissemination and the education of vegetated systems for urban development and renewal. The primary focus for GRA advocacy is green roof, living wall and green facade systems for the built environment which connect to deep soil landscaping as a holistic solution for environmental sustainability.
The goal is to promote a gradual transition from grey to green infrastructure based on qualitative and quantitative research data.

Background:

GRA was formed in 2006 as Green Roofs Australia and in 2010 included New Zealand to become known as Green Roofs Australasia.
The structure of GRA has evolved from an incorporated association to a registered company limited by guarantee with Not For Profit status.

The current Board of Directors are:
- President: Matthew Dillon
- Treasurer: Robert Griffith
- Secretary: Tanya Excell
- Board Members: Sidonie Carpenter; David Duncan; Ruzica Mohorko; Zoe Zimmerman (NZ)

Past President: Sidonie Carpenter

Membership:

GRA membership categories include: Students; Individuals; Sole Traders; Small Companies; Corporations; Universities and Institutions; Capital City and Local Governments.

Dissemination:

National Conferences aim to provide a mix of international and national keynote speakers and delegates with the latest developments in technology, research and design projects.
A comprehensive website provides members with a library; project gallery; image gallery; videos; news; events; a professional registry, technology companies and social media connectivity through FB, a blog and Twitter:- Follow us on #GRAustralasia

Associations:

GRA has developed associations with the Australian Institute of Architects; Australian Institute of Landscape Architects; Horticulture Australia; Landscape Contractors Association, Nursery & the National Gardens Industry of Australia

International Affiliation:

GRA was a founding member of the World Green Infrastructure Network (WGIN) and holds a Board Member position.

CONTACT:

GRA Head Office in Sydney, Aus.E: *info@GRaus.com.au*

HOMEPAGE:

www.greenroofsaustralasia.com.au

NUMBER OF MEMBERS:

864 single members with

Corporate members:

- Manufacturer:
- Distributer/supplier:
- Supplier of components:
- Living walls:
- Professionals:
- Nurseries, Landscape Companies:
- Local Government Councils
- Sole Traders; Individuals; Students

CITY PROGRAMS

Background:

GRA has been active in discussions with Australian Capital Cities regarding policy, research and appropriate incentive initiatives since 2006. Initially, all research data, guidelines, policy templates and best practice for specification, design and maintenance were based on a hybrid USA - European model. Keynote speakers such as Nigel Dunnet, Ed Snodgrass, Manfred Koehler and other notable experts were brought to GRA Conferences to share, inspire and educate a small community of professionals, academics and tradespeople. The aim for GRA in the early stages of industry development was to create a platform for dissemination and education through conferences, speaking engagements, media interviews, publications, building membership, international networking and a website. In 2007 a Labour Government swept to power with a mandate to address climate change primarily through a reduction of carbon emissions from large polluters. A Ministry for Climate Change & Water was formed which worked in conjunction with the Ministry for Environment. The mood of the country shifted with greater awareness for the environment and funds were available for climate change mitigation research. GRA continues to play a significant role as a stakeholder in research projects around Australia.

To date, the collaboration between the University of Melbourne (UoM) Burnley Campus and the City of Melbourne (CoM) has formulated a successful relationship which is an example for other Australian Capital Cities to follow. The UoM was the first to receive significant funding for green roof plant research and for the construction of a Green Infrastructure Adaption Centre, completed in 2012.

The City of Melbourne installed test green roof plots on council buildings; held a competition; began a community forum group 'Canopy'; sought community consultation; engaged the research assistance of Burnley and developed guideline drafts which were released as 'the Growing Green Guide' in 2013. http://imap.vic.gov.au/uploads/Growing%20Green%20Guide/Growing%20Green%20Guide%20FINAL%20DRAFT%20website4.pdf

www.land-environment.unimelb.edu.au/about-us/our-locations/burnley/

http://www.sciencedirect.com/science/article/pii/S1618866710000099

The development of green infrastructure in Sydney has largely been driven by clients and architects willing to absorb the additional costs associated with design and construction. The City of Sydney published Green Roof Guidelines in 2010, which were based on the German FLL issue. In 2013 a new Green Roof Policy was legislated and will be on trial until 2018, at which time the performances and the coverage will be monitored. Extensive CBD Canopy planting throughout the CBD is a response to mitigating the impacts of Urban Heat Island Effects. http://www.cityofsydney.nsw.gov.au/vision/sustainable-sydney-2030 www.cityofsydney.nsw.gov.au/.../109384/Green-roofs-and-walls-strategy.pdf - 2012-11-05 (http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0011/158870/attachment_a__draft_green_roofs_and_walls_policy1.pdf)

The State of South Australia has been progressive with research on green

infrastructure at all three universities and collaborations with Graham Hopkins and Christine Goodwin from Fifth Creek Studios. The Botanic Gardens of Adelaide published the Green Infrastructure Project which aims at bringing community, industry and government together to promote, demonstrate, guide policy and realise a transition towards a sustainable green urban environment.
www.environment.sa.gov.au/botanicgardens/Learn/Green_Infrastructure
http://www.sa.gov.au/upload/franchise/Housing,%20property%20and%20land/PLG/WSUD_chapter_6.pdf
http://web01.redland.qld.gov.au/robo/Minutes_Agendas/April_June10/Agendas%5CMay%5C5_May_PP%5CGreenRoofs_Appendix_2_policy_review.pdf
http://www.architectureanddesign.com.au/news/industry-news/w-a-yet-to-embrace-green-roofs

CONFERENCES:

Annual national conferences with an international focus since 2007. The conferences vary depending on the State with an average delegate attendance of 250 - 300. Local manufacturers participate providing the general public & professionals with technology information at the Expo category. International & National keynotes cover a range of green infrastructure topics over 3 days.

FURTHER ACTIVITIES:

Current working groups.
Rural Industry Research and Development Corporation (RIRDC)
Sustainable Built Environment, National Research Centre
VCCCAR; NGIA; Horticulture Australia; UTS Future Sustainability; UoM Adaption Centre; QUT; Fytogreen Australia; CSIRO; UNSW CRC; RBG SA; USA; UoA; SA Dept Land & Environment. Adelaide Botanic Gardens; Curtin University.
Water Sensitive Urban Design:
http://www.planning.sa.gov.au/go/wsud
http://scholar.google.com.au/scholar?hl=en&q=%22green+roof%22+Australia&btnG=&as_sdt=1%2C5&as_sdtp
www.cityofsydney.nsw.gov.au/.../greening-the-city/green-roofs-and-walls - 2013-11-21

MEMBERSHIP:

Founding nation member of WGIN

ACADEMIC RESEARCH INSTITUTIONS

-http://www.land-environment.unimelb.edu.au/research/research-groups/green-infrastructure-research-group/
- http://visions.unimelb.edu.au/episode/green-roofs-growing-research
-http://www.thefifthestate.com.au/archives/51540/
www.land-environment.unimelb.edu.au/about-us/our-locations/burnley/

Source: Matt Dillon.

- http://www.bpn.com.au/news/ queensland-joins-the-green-roof-revolution-
-http://www.aila.org.au/projects/SA/living_arch/default.htm
- http://www.zoossa.com.au/conservation-ark/research/projects?project=Attracting%20native%20wildlife%20to%20green%20roofs%20and%20walls%20at%20the%20Adelaide%20Zoo
-http://w3.unisa.edu.au/unisanews/2012/july/story1.asp
-http://www.ies.unsw.edu.au/sites/all/files/Njames-Gmetternicht_GRpolicy.pdf
-http://www.api.org.au/folder/journal/december-journal--up-on-the-roof
- HF Castleton, V Stovin, SBM Beck, JB Davison - Energy and Buildings, 2010 - Elsevie
http://www.greenroofs.com/pdfs/student-OptimumGreenRoofforBrisbane.pdf

HIGHLIGHTED NATIONAL SCIENTIFIC PUBLICATION

- Living Architecture; Hopkins & Goodwin (CSIRO Press)
- Living Wall & Green Roofs Plants for Australia;
- https://rirdc.infoservices.com.au/items/11-175
-www.environment.sa.gov.au/botanicgardens/Learn/Green_Infrastructure
- Bee Friendly: Planting Guide for Aust Pollinators;
-http://www.rirdc.gov.au/search-results?searchCriteria=bee+friendly

CURRENT TRENDS

Australasia is in transition from grey to green infrastructure, however research data specific to climates is required to qualify and quantify new policy before real progress can be acheived. There is a trend for all forms of green infrastructure including street canopy planting, park revegetation; green roofs, living walls and green facades. Perceived costs and risks are a present barrier which results in green facades and extensive green roofs proving cost efficient with less associated risks. Green buildings are in public demand and living wall signatures are included on new developments as a successful marketing tool for sales. The interest has recorded steady growth since 2007 and with recent media attention for large projects, new research data and greater awareness about the environmental, social and economic benefits demand, there are strong signs for a surging expansion towards 2020. Urban farming is a strong trend throughout suburban communities however as yet have not transcended to rooftops.

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

Graham Hopkins; Melinda Perkins; Steven Livesley; John Rayner; Sasha Cohen; Warwick Savvas; Prof Peter Newman; Charlie Hargroves; Dr Cheryl Desha; Mark Paul; Daniel Baffsksy; Matt Dillon; Sidonie Carpenter.

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

There is no comprehensive data for the growth expansion of green roofs, living walls and green facades. However, within Sydney inner suburbs there are presently 28 living walls covering 2,684.89 sq.m and 55 green roofs covering 85961.46 sq.m
Due to the cost of design, installation and maintenance for media based living walls and green roofs there has been a preference for green facade planting, especially for retro fit projects and car parks which require air circulation and filtered day light.
The real estate industry reports that sales for off plan on new developments sell faster if there are obvious green elements such as a green roof or wall. Such developments are marketed as 'green villiages' providing resident community activities.

Major Projects:

Victorian Desalination Plant, Wonthaggi, VIC (Architects: ARM/ Peckvonhartel;

Landscape Architects: Aspect Studios Melbourne.
Design, installation & maintenance: Fytogreen Australia)
Coastal dune revegetation and 263 hectares of revegetated native parkland including a 2.7 hectare extensive green roof over the plant.

Sydney Olympic Park, NSW. The Brownfield area of Homebush Bay was remediated from an area of landfill, abattoirs and a navy armament depots into a multiuse Olympic site using WSUD technology to ensure that the town remains 'nationally and internationally recognised for excellence and innovation in urban design, building design and sustainability.
Australian Parliament House, Canberra, ACT. (Architect: Romaldo Giurgola, 1985) Capital Hill was excavated to build the new Parliament House and the earth was replaced to recreate the hill form as a 40,000 sqm green roof planted with turf.

Origin Energy Building, Melbourne, VIC (Building Owner: Cromwell Group;
Living Wall Design, System, Installation by the GreenWall Company)
The tallest living wall in Australia is an internal continuous green spine down the central core of 22 floors to the foyer.

One Central Park, Sydney, NSW. (Architect: Jean Nouvel; Vertical Garden Design: Patrick Blanc. Construction: Frasers Group. Collaborating Landscape Architects: Aspect Studios Sydney) Planted 20-50 metre felt panels specified by PB with 500 species growing at altitudes of 10 - 150m. Also, planter boxes with spill planting and tensile s/s cables for creepers (Tensile Australia). At ground level a new 6,400 sqm green roof public park.

RECOMMENDED NATIONAL WEBPAGES:

www.greenroofsaustralasia.com.au

AREA: BELGIUM

National organization:
Belgische VerenigingGroendaken
en Gebruiksdaken (BVGG)

STRUCTURE AND MISSION:

The Belgian B.V.G.G. was founded in 2008. Our members are professionals active in the building and gardening industries. Our target group varies from architects, landscaping architects, building- and gardening companies to manufactures.
BVGG is a platform for the exchange of information and knowhow and the development of guidelines and norms in cooperation with governmental and specialized organizations.
The aim of B.V.G.G. is to promote the installation of green roofs, roof gardens and parking decks, to improve the quality of the environment.
Some manufacturers are already members of the BVGG (for example ATAB (IKO), Soprema) and other organisations (Dutch and German organisations for roof gardens), specialised organisations like BFG (Belgische Federatie Groenvoorziening), VVOG (Vlaamse Vereniging voor Openbaar Groen) and VBTA (Vereniging Belgische Tuinaannemer). There is also interest from governmental organisations.

CONTACT:

BVGG - Belgian Association of Green Roofs
Boomsesteenweg 46, Aartsellar 2630, Belgium
Service Areas: Belgium
Luc Tavernier, Chairman
http://www.ibic.be/
This is one member company.
Phone 0032 3 8433966, 0032 473 806 371; Fax 0032 3 8433967
Organizations > Non-Profits

CITY PROGRAMS

- The Brussels-Capital region: “Energy Premium 2012”
- Premium provided for the installation of insulation and ventilation systems, green roofs, photovoltaic solar panels, etc.
- Compulsory installation of green roofs for all non-accessible flat roofs over 100m^2
- Tax reduction and SME bonus for companies operating in the building sector
- Practical guides for green roof installation
- The Flanders region: “The Environmental Covenant”
- The Walloon region: no program

MEMBERSHIP:

EFB since 2008

GREEN ROOF RESEARCH INSTITUTIONS IN BELGIUM

- HUBrussel - KatholiekeUniversiteit Leuven (Claus, Dang Vu & Rousseau)
- Belgian Building Research Institute
- Centre Scientifique et Technique de la Construction (CSTC)
- Brussels Institute for Environment Management (IBGE)
- Brussels Enterprise Agency
- Centre de Référence
- Centre Urban

SELECTED NATIONAL SCIENTIFIC PUBLICATION

- Claus, K. & Rousseau, S. (2010). Public versus private incentives to invest in green roofs: A cost benefit analysis for Flanders. Hogeschool-Universiteit Brussels, 3-4.
- Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century. Hermy, Raes, Mentens. 2006. KULeuven.

CURRENT TRENDS

- Compulsory installation of green roofs in the Brussels-Capital region and the Flanders region
- Aids and incentives for the development of a green roof market
- Better awareness amongst relevant stakeholders
- Intensive green roofs are attracting more attention from customers than extensive ones

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

- Huytebroeck, E. (2010b). Brussels: from eco-building to sustainable city. Retrieved from -http://documentation.bruxellesenvironnement.be/documents/BxlVilleDurable_ANGL.PDF
- Luyckx, F. (2011). Les toitures vertes: Principes techniques et contexte bruxellois. Retrieved from -http://www.confederationconstruction.be/Portals/19/Cellule%20Energie%20Environnement/1.%20Facilitateur%20F.%20Luyckx%20_toitures%20vertes_CCBC.pdf
- Hermy, Raes, Mentens. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century. 2006. KULeuven
- Jean-Pierre Binamé
- Marc Hermans, Toan Dang Vu. Greenskin DVMH. http://www.greenskindvmh.com

RECOMMENDED NATIONAL WEBPAGES:

http://www.bbri.be
http://www.brusselsgreentech.be
http://www.cstc.be
http://www.curbain.be
http://www.deboer.be
http://www.floradak.be
http://www.greenskindvmh.com
http://www.ibic.be
http://www.derbigum.com
http://www.ibgebim.be
http://www.ieb.be

Newport, KY. Source: Greenroofs.com. Photo Courtesy of Christine & Jeff Salisbury. Landscape, health.

AREA: **BRAZIL**

National organization:
Associação Tecnologia Verde Brasil – ATVerdeBrasil
Rua Erechim, n. 330, Porto Alegre, Rio Grande do Sul, Brazil.
João Manuel Linck Feijó (President)

STRUCTURE AND MISSION:

The ATVerdeBrasil (Green Technology Association Brazil) is an activist, non-governmental, non-profit organization that aims to promote biophilic green infrastructure practices and technologies, such as green roofs, vertical gardens, permeable pavements, biophilic recycle and reuse of wastewater systems, urban forestry, urban agriculture etc.
ATVerdeBrasil was founded in 2009. At that time was called Associação Telhados Verdes para Cidades Saudáveis do Brasil (Green Roofs for Healthy Cities Brazil Association). Later, changed the name for Associação Telhado Verde Brasil (Brazil Green Roof Association) and, finally, since 2013 the institution is named as Associação Tecnologia Verde Brasil.

CONTACT:

ATVerdeBrasil office: Renan Eschiletti Machado Guimarães (Executive Secretary)

HOMEPAGE:

www.atverdebrasil.com.br

NUMBER OF MEMBERS:

1205 friendly members; 102 contribute members; 31 corporate members.

CITY PROGRAMS

The Association is working on the promotion of municipal tax incentives to disseminate green infrastructure technologies, and is helping to develop municipal public policies of green infrastructure and city contests related to it.

CONFERENCES:

ATV Brasil Lectures - TeCobI Expo 2012

FURTHER ACTIVITIES:

Promotion and management of events of green infrastructure technologies and policies; development of green infrastructure incentive policies; green infrastructure lectures in universities and schools.

MEMBERSHIP:

Member of WGIN,

ACADEMIC RESEARCH INSTITUTIONS

Partner of INVERDE (Instituto de Pesquisas em Infraestrutura Verde e Ecologia Urbana – Green Infrastructure and Urban Ecology Research Institute)

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

Cidades para Todos: (re) aprendendo a conviver com a Natureza (Cecilia Polacow Herzog, 2013, ed. Mauad X).

CURRENT TRENDS:

Promotion of green infrastructure technologies for urban farming and it utility for environmental education in schools; participation in discussions and development of green infrastructure public policies.

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

- João Manuel Linck Feijó
- Cecilia Polacow Herzog
- Jaime Lerner
- Renan Eschiletti Machado Guimarães
- Maria José de Mello
- Marina Silva
- Pérola Brocanelli

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

- About 40.000 m² green roofs each year.
- About 70% extensive, 30% roof gardens.
- About 2.000 m² green walls each year.
- Permeable pavement and green infrastructure integrate system for recycle and reuse wasted water are in the beginning.

RECOMMENDED NATIONAL WEBPAGES:

www.atverdebrasil.com.br

Source: Greenroofs.com. Photo Courtesy of Vegetal i.D.

AREA: BOLIVIA

National organization:
Ciudades Verdes Bolivia

STRUCTURE AND MISSION:

Ciudades Verdes Bolivia is a Bolivian collective that gathers individuals and institutions committed to the development of cities that promote citizens' well-being in harmony with the environment and principles of sustainability.

Mission:

To generate opportunities for people and institutions that are committed to the development of green cities in Bolivia to share ideas, experiences and best practices.

Vision:

Bolivia is a country characterized by green cities that are in harmony with the environment and offer social well-being.

ORGANIZATION STRUCTURE:

Ciudades Verdes Bolivia is a virtual network launched in 2014.
Directors:
- Maria Teresa Nogales (Fundación Alternativas)
- Gabriela Aro (Municipal Government of La Paz)
- Javier Valda (FAO – Bolivia)

CONTACT PERSON:

Maria Teresa Nogales
mtnogales@alternativascc.org

HOMEPAGE:

http://goo.gl/1LAZVo

NUMBER OF MEMBERS:

91

MEMBERSHIP:

Membership to Ciudades Verdes Bolivia is open to the public and free of charge. Ciudades Verdes Bolivia is an online platform that serves as a meeting place where individuals and institutions can share ideas, projects and proposals as well as inform others of best practices in addition to current local and international initiatives.

OTHER ACTIVITIES:

Ciudades Verdes Bolivia is an online platform that currently seeks to engage its members through virtual discussions and posts. Ciudades Verdes Bolivia places a special emphasis on leveraging its existing network to identify new members and, as such, introduce green ideas and concepts to a wider audience.

GREEN ROOF RESEARCH INSTITUTIONS

- CIDES-UMSA
- Fundación Milenio
- ,Fundación Tierra
- ,Dirección de Investigación Científica y Tecnológica (Cochabamba)

FUTURE TRENDS

Ciudades Verdes Bolivia will engage its current network through online discussions and posts in an effort to encourage members to share

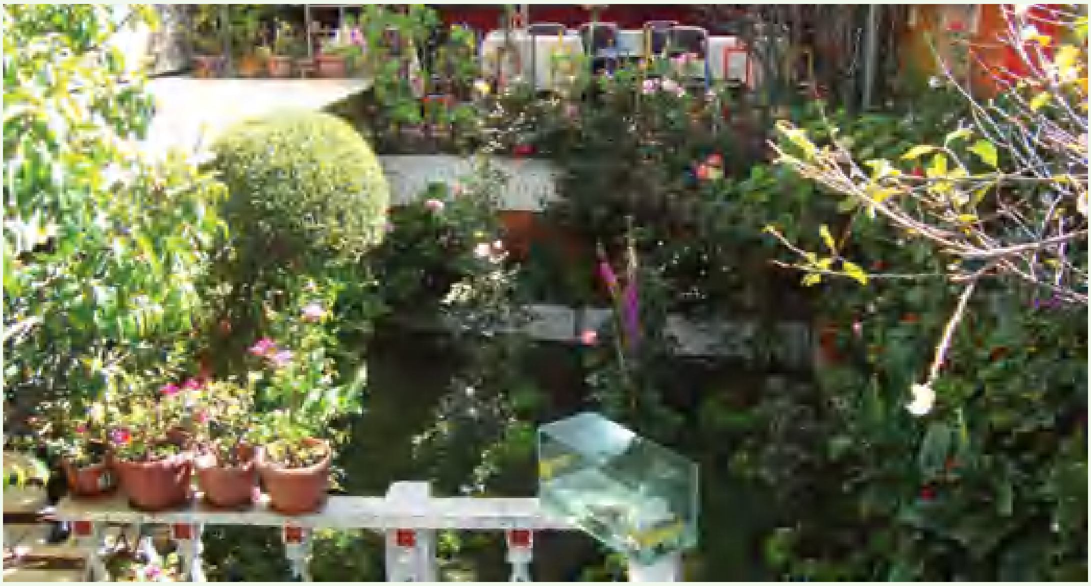
ideas, best practices and lessons learned related to green initiatives in Bolivia and around the globe.
Ciudades Verdes Bolivia will seek opportunities to organize events, presentations and other activities aimed at fostering greater visibility for national green initiatives.

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

- Professor Julio Prudencio (CIDES-UMSA), La Paz
- Professor Ivonne Farah (CIDES-UMSA), La Paz
- Lic. Bishelly Elias (Agrónomos & Veterinarios Sin Fronteras), La Paz
- Arq. Roberto Auchen (Representative Green Building Bolivia), La Paz
- Lic. Silvana Galindo (Gerente Parque Urbano Central), La Paz
- Lic. Stephan Von Borris (Environmental Consultant), Santa Cruz de la Sierra
- Ing. Rudy Guzman (Forestry Expert & Consultant), Santa Cruz de la Sierra
- Lic. Andrea Urioste (Fundación Amigos de la Naturaleza), Santa Cruz de la Sierra
- Lic. Maria Teresa Nogales (Fundación Alternativas), La Paz
- Lic. Andrea Ibañez Pantoja (Fundación Alternativas), La Paz
- Lic. Javier Thellaeche (Fundación Alternativas), La Paz
- Lic. Maria Julia Jimenez (Slow Food Bolivia), La Paz
- Ing.Carmen Sotomayor (AOPEB), La Paz
- Lic. Oscar Bazoberry (IPDRS), La Paz
- Lic. Anne Piepenstock (GIZ), La Paz
- Dr. Angélica Stemmer (Dirección de Investigación Científica y Tecnológica - Universidad Mayor de San Simón), Cochabamba

RECOMMENDED NATIONAL WEBPAGES:

www.gbcbolivia.org/
www.ftierra.org/
www.fundacion-milenio.org/
www.fan-bo.org/
www.lapaz.bo/index.php?option=com_content&view=article&id=6795:parque-urbano-central&catid=211&Itemid=657
www.facebook.com/FanaticosxlaNaturaleza
www.alternativascc.org
bolivia.blogresponsable.com/
https://www.facebook.com/SlowFoodBolivia
http://www.redesma.org/



Green roof La Paz. Source: I. de Felipe.

AREA: USA / CANADA

National organization:
Green Roofs for Healthy Cities
406 King Street East
Toronto, ON
M5A 1L4
Canada

STRUCTURE AND MISSION:

Green Roofs for Healthy Cities North America

Organization Background and Objectives:

In 1999, Green Roofs for Healthy Cities, a small network consisting of public and private organizations, was founded as a direct result of a research project on the benefits of green roofs and barriers to industry development entitled "Greenbacks from Green Roofs" prepared by Steven Peck, Monica Kuhn, Dr. Brad Bass and Chris Callaghan. Green Roofs for Healthy Cities - North America, Inc. is now a rapidly growing not-for-profit industry association working to promote the industry throughout North America. In 2004, Green Roofs for Healthy Cities became a formal industry association registered as a not-for-profit 501(c) (6). Our Board Members include:

Current Board of Directors as of Nov. 2014:

- Chair: Jeffrey Bruce, *Jeffrey L. Bruce & Co. LLC.*
- Immediate Past Chair: Peter Lowitt, *Devens Enterprise Commission*
- Treasurer: Paul Sheehy, *Tremco Canada.*
- Chair, Corporate Members Committee: Oscar Warmerdam, *Sempergreen USA*
- Chair, Policy Committee: Hamid Karimi, Ph.D., *Government of the District of Columbia*
- Chair, Research Committee: Virginia Russell, University of Cincinatti
- Chair, Green Infrastructure Foundation: Michael Krause, *Kandiyohi Development Partners*
- Chair, Technical Standards Committee: David Yocca, *Conservation Design Forum*
- Legal Counsel, Tricia Dunlap, McQuire Woods LLP
- Director at Large, Gaelle Berges, Vegetal ID
- Director at Large Matt Barmor, Firestone Building Products
- Richard Hayden, American Hydrotech
- President: Steven W. Peck, *Green Roofs for Healthy Cities*

MISSION STATEMENT

Green Roofs for Healthy Cities' mission is to develop and protect the market by increasing the awareness of the economic, social and environmental benefits of green roofs, green walls, and other forms of living architecture through education, advocacy, professional development and celebrations of excellence.

ORGANIZATIONS- STRUCTURE:

Non-profit, non-government organization

CONTACT PERSON:

Steven W. Peck, Founder and President

HOMEPAGE:

http://www.greenroofs.org

DEDICATED GREEN ROOF CITY PROGRAMS AND YEAR OF IMPLEMENTATION

- King County, WA: 2004
- Portland, OR: Ecoroof, 2005, Clean river rewards 2006
- Minneapolis, MN: Stormwater, 2005
- Chicago, IL: Green permit program, 2006
- Port Cocuitlam, BC: Green roof regulation, 2006
- Washington DC: Green roof rebate program, 2007
- Philadelphia, PA: Green roof tax credits, 2007
- Seattle, WA: Green factor 2007
- Richmond, BC: Green roof bylaw, 2008
- Anne Arundel County, MD: Stormwater tax credit, 2008
- New York City, NY: Green building construction act, 2009
- Toronto, ON: Green roof bylaw and Eco roof incentive program, 2008
- Bloomington, IN: Unified development ordinance, 2009
- Ohio: Environmental protection agency green roof loan program, 2009
- Milwaukee, WI: Metropolitan sewerage district regional green roof initiative, 2019
- Onondaga County NY: Green improvement fund, 2010
- Wisconsin: Vegetated roof systems guidelines, 2010
- Devans, MA: Policy for the construction of green roofs, 2011
- Austin, TX: Green roof density bonus, 2011

MEMBERSHIP:

Founding member of WGIN

FURTHER ACTIVITIES:

- Printed publication: Living Architecture Monitor (quarterly journal) (www.livingarchitecturemonitor.com)

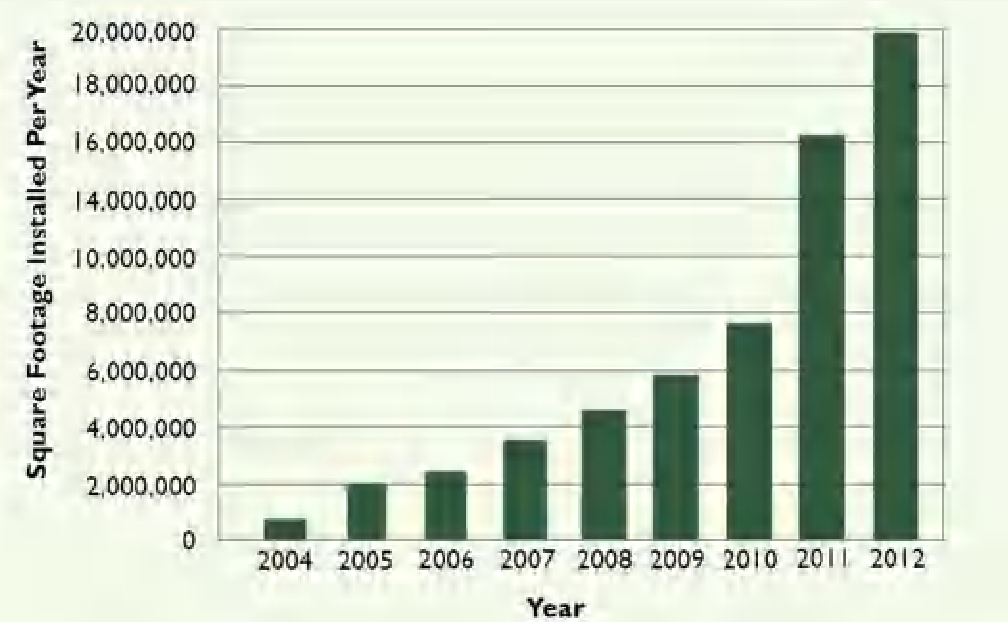
Olympic and Paralympic Village. City of Vancouver, B.C. Source: Greenroofs.com; Photo Courtesy of Vitaroofs International Inc.

- Green roof professional trainee and accreditation courses; as of 2012, about 525 people have successfully obtained this qualification. (See www.greenroofs.org for details of inperson training. To purchase training manuals visit www.greeninfrastructure store.com)
-Green roof calculator (members only online life-cycle green roof cost benefit calculator)
-Annual conferences since 2003 (Location: Chicago 2003, Portland 2004, Washington DC 2005, Boston 2006, Minneapolis 2007, Baltimore 2008, Atlanta 2009, (Toronto – WGIN 2009), Vancouver 2010, Philadelphia 2011, Chicago 2012, San Francisco 2013, Nashville, 2014)
-Several trainee courses, from basic knowledge up to highly specialized courses
-Literature data bank on scientific papers called: the "Tree of Knowledge" under Resources at www.greenroofs.org

RESOURCE MANUALS AND BOOKS – See www.greeninfrastructurestore.com to order

The Rise of Living Architecture Commemorative Edition Book
The Rise of Living Architecture is a unique table top book that profiles more than 50 leaders that have fueled the explosive growth of green roofs and walls across North America over the past decade. It includes a forward on Biophilic Design by Stephen Kellhert of Yale University and a trend essay by Steven W. Peck, GRP, president and founder of GRHC. Full color, 149 pages.
Green Roof Design and Installation (course manual) NEW!
Green Roof Design and Installation is an updated and consolidated version of our Green Roof Design 101 and Green Roof Design and Installation 201 course manuals. It contains new research, the latest technical standards and more. Core course material for Green Roof Professional accreditation exam. Color images, 307 pages.
Green Roof Waterproofing and Drainage (course manual)
Overview of the many tools and techniques needed to meet green roof waterproofing and drainage project objectives. Includes: waterproofing and drainage terminology, waterproofing and drainage assemblies and systems, overview of major design principles and much more. Core course material for Green Roof Professional accreditation exam. Color images, 118 pages.
Green Roof Plants and Growing Media (course manual)
This manual provides an overview of plants and growing media design considerations and maintenance for green roof assemblies, design and implementation best management practices, principles of plant physiology and soil sciences and more. Core course material for Green Roof Professional accreditation exam. Color images, 121 pages.
Advanced Green Roof Maintenance (course manual)
This manual examines the planning and implementation of maintenance of green roofs. This course manual includes detailed information on developing maintenance plans, contracts and inspection reports that work to comply with warranty requirements. Color images, 111 pages.
Green Infrastructure: Policies, Performance and Projects (course manual)
This manual provides a review of various vegetative technologies in urban areas (i.e. green walls, roofs, urban forests, rain gardens), presents the latest research on their many performance benefits, and showcases a variety of leading edge policy and program developments in cities such as Chicago, Seattle, New York and Toronto. Color images, 252 pages.
Green Walls 101: Systems Overview and Design (course manual)
This manual presents an overview of the many tools and techniques needed to satisfy your green wall project objectives. The course manual identifies green wall cost factors and benefits, the different types of products available, major design principles and how to avoid the types of mistakes that might lead to an unsuccessful project. Color images, 96 pages.

ESTIMATED GROWTH OF THE NORTH AMERICAN GREEN ROOF INDUSTRY



Introduction to Integrated Water Management for Buildings and Sites (course manual)
Introduction to Integrated Water Management applies green roofs and walls to the "Net Zero Water" concept. Through the effective implementation of green roofs and walls, this manual approaches strategies to significantly reduce the consumption of potable water on buildings in order to deliver sustainable living systems to urban environments. Color images, 97 pages.
Integrated Water Management for Buildings and Sites II: Case Studies (course manual)
This course manual builds upon information in our first edition. Achieving net-zero water utilizes the concepts of using and reusing water multiple times on site. This manual focuses on case studies from different regions and explores in detail the design, installation, maintenance, policy and economic realities of these systems. Color images, 82 pages.
Integrated Water Management for Buildings and Sites III: Water Storage and Cisterns (course manual)
The desired outcome of the Integrated Water Management Educational Series is to capture the most advanced concepts and technologies available. This course manual is the third in the series and will focus on water storage and system components. Color images, 103 pages.
Introduction to Rooftop Urban Agriculture (course manual)
Learn about multiple approaches to growing food on rooftops through design and maintenance principles, and case studies drawn from across North America. The manual covers multiple approaches to growing food on rooftops through design and maintenance principles, as well as case studies drawn from across North America. Color images, 86 pages.
Living Architecture and Sustainable Energy (course manual)
This manual provides a holistic approach to energy conservation and production utilizing living architecture technologies. Topics covered: envelope heat loss and gain, intake air cooling, cooling of rooftop photovoltaic panels, use for condenser heat rejection, and day lighting. Color images, 100 pages.
CitiesAlive 2003-2012 Conference Proceedings USB
This USB drive contains over 350 technical

*New York.
Green terrace
Source:
I. de Felipe.*

papers from GRHC's past ten conferences—a wealth of information on green roof policy, design, and research.

GREEN ROOF RESEARCH INSTITUTIONS IN NORTH AMERICA:

- Penn State University, Robert Berghage, Robert Cameron, et al.
- Michigan State University, Brad Rowe, and others http://www.hrt.msu.edu/greenroof/
- University of Guelph, Prof. Youbin Zheng http://www.ces.uoguelph.ca/greenroof/research.shtml
- BCIT, British Columbia Institute of Technology, Vancouver (Maureen Connelly)
- St. Mary's University in Halifax (Halifax, NS, Canada), Jeremy Lundholm
- Southern Illinois University, Edwardsville, Prof. Bill Retzlaff http://www.siue.edu/engineering/green-roof.shtml
- University of Toronto, ON, CA, Brad Bass
- Portland State University; Portland OR, Greg Haines http://ecoroofseverywhere.com/2009/10/portland-state-university-lab-roof/
- Lady Bird Johnson Wildflower Center at University of Texas, Austin Texas, Prof. Mark Simmons, http://www.utexas.edu/opa/experts/profile.php?id=634 http://www.wildflower.org/greenroof/
- Texas A & M University, College Station, TX http://hortsciences.tamu.edu/
- Oak creek Center for Urban Horticulture at Oregon State University, Corvallis, OR http://horticulture.oregonstate.edu/content/oak-creek-center-urban-horticulture-5th-annual-field-day
- University of Cincinnati, Cincinnati, OH,

Prof. Virginia Russell http://www.uc.edu/af/pdc/sustainability.html
- Chicago Botanic Garden Plant Science Center, Glencoe, IL, Kelly Ksiazek, Richard Hawke http://www.chicagobotanic.org/research/building/green_roof.php
- Oklahoma University Division of Landscape Architecture, Norman, OK http://www.ou.edu/architecture/ landscape_architecture.html
- University of Maryland, College Park, MD, Steven Cohan http://www.psla.umd.edu/faculty/cohan.cfm http://www.sustainability.umd.edu/content/campus/green_buildings.php

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

Many; a search in Science Direct yields over 200 peer-reviewed publications from North America

CURRENT TRENDS:

Rooftop agriculture;
http://www.urbanagsummit.org/

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

An overview is summarized in: Peck, S., 2013: *The Rise of Living Architecture*, GRHC, Toronto, Canada

RECOMMENDED NATIONAL WEBPAGES:

http://www.urbanagsummit.org/
www.greeninfrastructurestore.com
www.livingarchitecturemonitor.com
www.greeninfrastructurefoundation.org
www.greenroofs.org
www.citiesalive.org
www.greytogreenconference.org

AREA: CHINA

National organization:
International Rooftop Landscaping Association
Room 105, Building 4, Construction Yard, Sanlihe Road,
Haidian District, 100037, Beijing, China
Tel: 86-10-67115339 Fax: 86-10-68312977
e-Mail: wrgmay2010@hotmail.com

STRUCTURE AND MISSION:

International Rooftop Landscaping Association (IRLA) was established by green roof volunteers, and officially registered as a non-profit social organization in the United States on Aug. 7th, 2009. IRLA has set up many offices around the world, with the Asian/Pacific region's office located in China, where the secretary-general Prof. Xianmin Wang takes charge of the daily activities.

IRLA's aim is to organize and unite green roof workers, promote world peace, and protect the environment, construct low-carbon, energy-saving, liveable and well-landscaped ecological environments, carry out rooftop farming, develop roof agriculture, improve land use efficiency, and facilitate the sustainable development of human society.

IRLA's professional field includes green roofs, green walls, indoor greening, etc; carbon construction, energy-efficient buildings, land use efficiency, rainwater collection and application, rooftop farming, and ecological restoration protecting, planning, constructing and managing.

IRLA's principal activities:

- To organize international academic exchange activities, promote technological development and cooperation;
- To popularize new technologies, and call on people participating in greening to beautify our living environment;
- To issue green roof development related awards;
- To carry out professional education research and promote professional training.

Every year, IRLA has a conference on vertical greening. In 2014, the conference will focus on the "Ecocity."

CONTACT PERSONS:

- Zhiqiang Wu (President)
- Xianmin Wang

HOMEPAGE:

www.greenrooftops.cn

NUMBER OF MEMBERS:

IRLA now has 130 company members, including construction companies, manufacturers, designing institutes, and material and plant suppliers. There are also 4,000 individual members in the association.

CITY PROGRAMS

- Beijing, 2011: promoting vertical greening in its documents.
- Shanghai, 2012: different subsidies according to the scale of vertical greening projects.
- Tianjin, 2013: planning to construct 100,000 m^2 of green roof gardens annually.
- Shenzhen, Guangdong Province, &Chongqing, 2013: add vertical greening into its regulations.
- Henan Province, 2013: formulating normative documents on green roof technologies.

Roof gardens in the style of a Chinese garden in Hangzhou. Source: M. Köhler.

CONFERENCES:

Annual international conferences since 2010:
- 2010 Shanghai World Green Roof Conference, with about a thousand attendees;
- 2011 Hainan World Green Roof Conference, also with hundreds of attendees from all over the world;
- 2012 Hangzhou World Green Roof Congress, annual meeting of WGIN, with about 1,500 people;
- 2013 Nanjing World Green Roof Congress, with hundreds of attendees.
- In 2014, the name will be changed to the International Ecocity and Green Roof Conference at Qingdao, Shandong Province.

FURTHER ACTIVITIES:

Professional trainings are held every year all over China, such as in Shanghai, Chongqing, Shenzhen, Qingdao, Dalian and Beijing. The meetings are about vertical greening materials, technology and design.
Annual conferences are held in different cities. Beginning in 2014, there will be training on specific technologies and vertical greening skills, such as irrigation, plant selection and ecological bags to protect slopes. Most importantly, experts will teach trainees by actually doing it on their own.
In Qiandeng, IRLA and the local government established a base to turn Qiandeng into an ecotown by 2018.
In Suzhou, IRLA and the local government established a design institute to learn from world-class designers and build world-class vertical greening projects in China (2013).

MEMBERSHIP:

Founding member of WGIN

ACADEMIC RESEARCH INSTITUTIONS

- School of Architecture, Tsinghua University: http://www.arch.tsinghua.edu.cn/chs/index.htm
- College of Architecture and Landscape Architecture of Peking University:

http://www.cala.pku.edu.cn/
- Beijing Institute of Landscape Arvhitecture: http://www.bjylkys.com/
- Shanghai Academy of Agriculture Sciences: http://www.shnky.com/
- Zhejiang Academy of Agriculture Sciences: http://www.zaas.ac.cn/
- Shanghai Jiaotong University School of Agriculture and Biology: http://www.agri.sjtu.edu.cn/
- Shenzhen Institute of Garden Sciences

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

Books: *Green Roofs, Vertical Greening in Beijing Olympic Games, Vertical Greening in Shanghai Expo Garden, Roof Garden Design and Case Study*
Journals: *Building Science and Technology, Chinese Landscape Architecture*

CURRENT TRENDS:

Green roofs, green walls, hanging gardens, roof farming, roof lawns and underground garage greening.

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

Prof. Xianmin Wang, Dingguo Zhao, Prof. Zhaolong Wang, Lili Han, Yifan Tan

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

About 12,000,000 m² total green roofs with a rate of increase about 20% to 25%, mostly in extensive gardens.
Green facades with climbers are common in many cities.
Vertical greening is developing very fast in China, but due to it being in the beginning stages, large-scale projects are not yet common. Also, because vertical greening just started in China, the markets are very promising.

RECOMMENDED NATIONAL WEBPAGES:

www.greenrooftops.cn,
http://www.yuanlin.com/

AREA: COLUMBIA

National organization:
Red Colombiana de Infraestructura Vegetada. RECIVE,
Calle 42 No. 8a-80 Oficina 1301
Bogota D.C.
Colombia

STRUCTURE AND MISSION:

RECIVE is a non-profit professional network, aiming to promote the development of green infrastructure in Colombia as:
- A responsible practice that enhances environmental quality and promotes well-being.
- A long-standing and feasible technology.
- A successful and sustainable market.

To achieve this objective, our multidisciplinary group of experts conducts activities in five strategic cores of work:
a. Promotion and education
b. National database
c. Assessment and certification
d. Technical advice and regulations
e. Innovation and development

RECIVE was founded in 2011 after initial development of green infrastructure over the last 4 years:
-More than 60 implementations in public and private projects.
-More than 60,000 m^2 of infrastructure greened.
-Formulation of the multi-scale function-based Green Roof Guidelines of Bogota (By-law 418, 2009).
-Inclusion of Colombia as a member of the World Green Infrastructure Network since 2010.
-Co-founding of ALIVE, Asociación Latinoamericana de Infraestructura Verde (Latin American Green Infrastructure Association), 2010.
-Participation in the World Congresses in Mexico, 2010; China, 2011; France, 2013; and Singapore, 2013.
-Participation in research and development projects in academia at the undergraduate and graduate levels, National University of Colombia, Humboldt University (IASP), and Universidad Piloto de Colombia.
-More than 60 publications in mass media journals, technical magazines, academic journals and international websites.
-Technical advice to various government entities.

ORGANIZATION –STRUCTURE:

Non-profit, non-government organization.

Committees:
- Technical and scientific. Director: Andrés Ibáñez G.
- Financial sustainability. Director: Pablo Atuesta
- Communications. Director: Luis Alberto Suarez
- Advisory and education. Director: Bio David Perico
- Policy and regulations. Director: Miguel Angel Cardenas

Board of directors:
- Chair: Andrés Ibáñez G.
- Vice-chair: David Perico
- Treasurer: Pablo Atuesta
- Secretary: Luis Alberto Suarez

Source:
A. Ibañez.

CONTACT PERSONS:

Andrés Ibáñez G.
raibanez@hotmail.com

HOMEPAGE:

www.recive.org

NUMBER OF MEMBERS:

- Founding companies: 4
- Regular members: 6
- Executive members: 4
- Sponsor members:
- Honorary members: 1

CITY PROGRAMS

- Bylaw 419, 2009, promotion of green roofs in Bogota.
- Biotic Roofs Guidelines, Secretary of Environment, Bogota, 2012.
- Biotic Walls Guidelines, Secretary of Environment, Bogota, 2013.
- http://ambientebogota.gov.co/web/una-piel-natural-para-bogota//consulta-la-guia-tecnica-de-techos-verdes-para-bogota
- Urban agriculture program, Municipality and Botanical Gardens.
- Sustainable construction code, under development.
- Colombian environmental construction label. ICONTEC, 2013.
- Environmental Observatory, environmental reporting, Secretary of Environment, Bogota. http://oab.ambientebogota.gov.co/observadores/reports/submit

CONFERENCES:

- A natural skin for Bogota, conference 1 on Vegetated surfaces.
- A natural skin for Bogota, conference 2 on Vegetated surfaces. Aug 13-15, 2013
- A natural skin for Bogota, conference 2 on Vegetated surfaces. Nov 15, 2013
- http://ambientebogota.gov.co/web/una-piel-natural-para-bogota/memorias-del-evento
- http://ambientebogota.gov.co/web/una-piel-natural-para-bogota

MEMBERSHIP:

Founding member of LAGIN, member of WGIN

ACADEMIC RESEARCH INSTITUTIONS

- National University of Colombia http://www.unal.edu.co/english/
- Universidad de Los Andes http://www.uniandes.edu.co/
- Pontificia Universidad Javeriana de Colombia http://www.javeriana.edu.co/puj/english/
- Universidad Piloto de Colombia http://www.unipiloto.edu.co/
- Universidad del Bosque http://www.uelbosque.edu.co/en
- Escuela Colombiana de Ingeniería http://www.escuelaing.edu.co/es/
- Universidad de Antioquia http://www.udea.edu.co/portal/page/portal/EnglishPortal/EnglishPortal
- Universidad EAFIT http://www.eafit.edu.co/english/Paginas/english-version-universidad-eafit-medellin-colombia-south-america.aspx
- Universidad del Valle http://www.univalle.edu.co/english/
- Universidad de Nariño http://www.udenar.edu.co/

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

Biotic Roof Guidelines. Guia Tecnica de Techos Bioticos de Bogota, Secretaria Distrital de Ambiente, 2012.
Techos Vivos: Sistemas constructivos de techos verdes extensivos en Bogota. Ibáñez Gutiérrez, Andrés, Master's thesis, Master of Building, National University of Colombia, Bogotá, 2009.
Modelación física de un techo verde extensivo para la aplicación de un sistema de drenaje urbano sostenible. León Fandiño, Eduardo Alfonso, Master's thesis, Master in Engineering - Hydraulic Resources, Faculty of Engineering, National University of Colombia, 2012

CURRENT TRENDS:

- Ecologically specialized biotic roofs
- Eco-productive biotic roofs
- Micro infrastructure (bus stops)
- Sustainable urban drainage systems
- Social urban farming
- Biotic walls and advertising
- Locally developed technologies
- Substrates with recycled materials
- Substrates with natural organic fibers

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

- Andrés Ibáñez G.
- Miguel Angel Cárdenas P.
- Alejandra Rincón
- Andres Martinez
- Diana Wiesner

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

The average area of biotectonics implemented per year in Colombia since 2009 is estimated at 12,796 square meters. 82% of the potential market is concentrated in 5 strategic zones: Capital region, Paisa Region, Santander, Costal region, and Valle del Cauca. Bogotá accounts for one quarter of the overall market available in the country.
New developments accounted for 81.27% of the number of projects intervened with biotectonics, and retrofit projects for 18.73%.
By the end of 2012, the total area of building surfaces greened (biotic roofs and walls) had reached 60,000 square meters.
Three building uses contributed the most to the increase in vegetated surfaces in urban areas: Commercial (38.6%), Office (18.5%), Hotels (8.5%) and Institutional (7.5%).
The area of biotic wall installation has been growing significantly in the last year, but there is no data available.

RECOMMENDED NATIONAL WEBPAGES:

www.recive.org

AREA: FRANCE

National organization:
ADIVET, Association des toitures et façades végétales
85, rue Gabriel Péri, 92120 Montrouge, France
e-mail: contact@adivet.net
François Lassalle, president
Marc Lacaille, general delegate

STRUCTURE AND MISSION:

Established in 2003, Adivet is a non-governmental, non-profit organization to promote all national activities of green roofs (extensive, semi-intensive and intensive) and green façades. The association brings together the key players in the green roof and green wall industry (manufacturers, waterproofing and landscaping contractors, professional associations, etc.). It recently expanded to encompass the green wall industry, a sector in which many of its members have been present for several years.
Concerning the green roofs, the hard work and dedication of the association and its members in recent years, (training/information/experimentation) has resulted in a boom in green roofs in France, with more than one million square meters installed in 2011. Adivet is also recognized as a reference organization in its field and is co-editor of the French Professional Standards for Green Roofs and Terraces, together with the UNEP (National Union of Landscaping Companies) and the CSFE (French Waterproofing Association).

CONTACT:

François Lassalle
francois.lassalle@adivet.net

HOMEPAGE:

www.adivet.net

NUMBER OF MEMBERS:

About sixty

CITY PROGRAMS

- Cities involved in green roofs/green façades:
  - Paris (Plan Local d'Urbanisme, Plan biodiversité)
  - Lyon
  - Grenoble
- National environmental process « Grenelle de l'environnement», launched by former president Sarkozy, and still working.

CONFERENCES:

Technical symposiums since 2004, in association with:
- CSTB (national building technical council)
- different CAUE (departmental architecture councils)
- CRITT ARRDHOR (technical center for horticulture)

Together with the WGIN, organization of the World Green Infrastructure Congress (Congrès mondial de la végétalisation du bâtiment) in Nantes, September 2013). Over 70 speakers, 500 delegates

MEMBERSHIP:

National:
- Plante &Cité (www.plante-et-cite.fr)
- CSFE (www.etancheite.com)

Green wall in France. Source: I. de Felipe.

- Betocib (www.betocib.net)
- Association HQE (www.assohqe.org)
- France GBC (www.francegbc.fr)

International:
- founding member of the WGIN since its launch (2007)
- member of the EFB (2013)

ACADEMIC RESEARCH INSTITUTIONS

- CSTB (Paris)
- Ecole des Ponts et Chaussées (Marne la Vallée, 77)
- Ecole des Mines (Paris)
- CEREMA (Bron, 69)

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

Règles Professionnelles pour les toitures et terrasses végétalisées
(editions in 2004, 2007, 2014)
Directives Professionnelles pour les façades végétalisées (writing in progress)

CURRENT TRENDS:

- More biodiversity on green roofs
- Rooftop farming

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

- François Lassalle (Adivet)
- Raphaël Lamé (Adivet)
- Olivier Damas (Plante et Cité)

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

- About 1,500,000 m² green roofs each year.
- About 90% extensive, 10% semi-intensive
- Roof gardens (intensive green roofs) also about 1,000,000 m²/year.
- Green facades exist in many cities and this market is growing.

AREA: GERMANY

National organization:
FBB Fachvereinigung Bauwerksbegrünung e.V.
Kanalstraße 2 D-66130 Saarbrücken.
Tel: 0049 -681-9880570 .
Dr. Gunter Mann (President)

STRUCTURE AND MISSION:

The FBB (Association of green buildings in Germany) is a non-governmental, non-profit organization to promote all national activities of green roofs (extensive and intensive), green facades and other technology and greenery-related functions in architecture.
The FBB was founded in 1990 as a forum for producers, retailers and planners.
The FBB includes green roof companies and some related professionals to promote the idea of "green architecture."
The FBB takes over part of the duties of the FLL; the focus of the FBB is to promote the greening building idea. The FLL concentrates on the development of guidelines.
Associations of neighboring countries are also welcomed as members. There is a close cooperation between the FBB and the FLL.
The 110 members from various fields, like companies, architecture offices and researchers, are the core of the FBB. The FBB has existed since 1980. Feel free to surf around to all the sub-sites of the FBB. Our main activities are investigations about governmental implementation of city greeneries. We also conduct investigations about national and local incentive programs to support green roof policy and promote green roof technology in all kinds of publications to all interested persons. Each year a national conference is held in March (FBB-Symposium Ditzingen) to focus the on-going developments in green roof technologies. The FBB international is one of the working groups within the FBB. It is the stairway to green roof organizations in Europe and around the world. Three FBB representatives are responsible for this. Please feel free to contact them with any questions.
There are different working groups, such as legal regulation, plant species recommendations, maintenance and more.

CONTACT:

FBB office, for WGIN: Manfred Koehler

HOMEPAGE:

www.fbb.de

NUMBER OF MEMBERS:

About 110. Including manufacturers: 27
Others: 83 more http://www.fbb.de/mitglieder?filtercat=5
(there are also members within the FBB: The associations from Switzerland, Italy and Austria)

CITY PROGRAMS

Three surveys about regulation in legal building plans (Bebauungspläne) have been done by the FBB; a questionnaire sent to about 1488 Cities with more than 10,000 inhabitants was answered by 564 cities. There is a wide range of policies from incentives to regulations following the nature conservation act.
Details of the results: http://www.fbb.de/dachbegruenung/foerderung/
Green roof policies are closely connected to rain water management activities in most of the cities.

Incentives range from 10 Euro/square-meter, mostly with a coverage of the total sum for a complete project. These can be combined with rain water incentives. This is roughly 1€/square-meter per year.

CONFERENCES:

Annual national conferences with an international focus have been held since 2003 in Ditzingen near Stuttgart. Up to 200 people participate. This is the annual exchange of the national green infrastructure association with an additional look at some other countries.
Annual façade seminars have taken place since 2008; since 2012 they have taken place in Frankfurt.
2011: Election of the green roof of the last decade.
Each year a selection process of the best green roofs is carried out by the members.

FURTHER ACTIVITIES:

Current working groups:
PG1: Roof terraces in timber
PG2: Root resistant layers
PG3: Green facades
PG4: Nuremberg trade show group
PG5: Risk analysis of green roofs (fall protection)
PG6: Percolation gutter systems on roof terraces
PG7: Cost – benefit analysis of green roofs and green facades
PG8: Maintenance of green roofs
Further international cooperation in the EFB and WGIN

MEMBERSHIP:

Founding member of EFB, founding member of WGIN

ACADEMIC RESEARCH INSTITUTIONS

- Technical University: http://www.tu-berlin.de/oekosys/
- Humboldt University Berlin, IASP: http://www.iasp.asp-berlin.de/
- Forschungslabors für Experimentelles Bauen (FEB) am Fachbereich Architektur Stadtplanung Landschaftsplanung der Universität Kassel. (1976´5-2011), Prof. em. G. Minike, http://cms.uni-kassel.de/asl/fo/foif/feb/

Extensive green roof example in Berlin. Source: M. Köhler.

- TU Darmstadt; http://www.freiraum.architektur.tu-darmstadt.de/freiraum/publika_freiraum/pfoser_veroeffentlichungen.de.jsp
- University Hannover, Prof Lösken http://www.ila.uni-hannover.de/loesken.html
- University of Applied Sciences Neubrandenburg, Green roof center, Prof. Dr. Manfred Koehler http://www.gruendach-mv.de/
- University of Applied Sciences Weihenstephan, Prof. Jauch, http://www.hswt.de/fgw/infodienst/2012/februar/dachbegruenung.html
- Technical University Munich http://www.tum.de/die-tum/publikationen/tumcampus/artikel/article/30103/
- Hochschule RainMain, Prof. Dr.-Ing. Stephan Roth-Kleyer http://www.hs-rm.de/fbg/ueber-uns/personen/personalseiten-fb-geisenheim/prof-dr-ing-stephan-roth-kleyer/index.html
- Research Institution Veitshöchheim http://www.lwg.bayern.de/

*There are more academic institutions with detailed studies.

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

FLL- Guidelines in relation to greening buildings
FLL-Green roof guidelines (latest issue: 2008, also in English, download available)
Further related FLL-Guidelines for indoor greening (2011), green façades (in print in 2014), as well as further related guidelines.
FLL-paper: selected plant species for green roofs, information about maintenance, root protection, and more: www.fbb.de
More than 1000 scientific papers about green roofs and green facades are in a data pool of the FBB. Only a minority of these are published in English.

CURRENT TRENDS:

-Urban farming
- Roof gardens as urban open spaces
- Solar-PV-green roofs
- Green roofs as part of a rain water management strategies

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

- Prof. H.J. Lieseke,
- Fritz Hämmerle

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

About 10 million square meters of green roofs each year.
About 85% extensive roofs and 15% roof gardens.
Green facades with climbers are common in many city incentive programs.
Living walls are now also becoming popular in Germany but the growth is still at the beginning. The breakthrough will occur with the publishing of the new living wall guideline in 2014.

RECOMMENDED NATIONAL WEBPAGES:

www.fll.de

AREA: HONG KONG

WGIN Partner:
Prof. C.Y. Jim, University of Hong Kong, Department of Geography, Pokfulam Road, Hong Kong. Tel: 852-3917-7020;
Fax: 852-2559-8994; Email: hragjcy@hku.hk;
Webpage: http://geog.hku.hk/staff_FT_jim.html

CITY PROGRAMS

About 25% of the 1050 km² of Hong Kong is high-density urban areas. As one of the most compact cities in the world, both commercial and residential high-rise buildings with 20–50 stories are common. Most rooftops are flat but largely barren and covered with concrete tiles. The green roof movement in Hong Kong was initiated in 2005 by the University of Hong Kong. Green roofs have been promoted by the government since 2008, spearheaded by the Architectural Services Department. Since 2012, green roof and green wall promotion has been taken on by the Hong Kong government, under its Greening, Landscape and Tree Management section of the Development Bureau.
The territory's first open competition, the Skyrise Greenery Award, was organized in 2012 by the government, together with professional bodies associated with the construction and property development sector. It aimed at encouraging more installation of green roofs and better green roof design and management. A total of 113 very high quality projects participated in the contest. They fell under four categories; government projects, private developments, schools and non-government organizations, and planning-research studies. The panel of judges chose 27 outstanding projects for the coveted award. Most green roofs are extensive. Thus far, only two intensive sites in the form of sky woodland have been established by a local power company (CLP) on the top of electricity substations embedded in built-up areas. Green roofs and green walls have continued to be installed on new buildings, accompanied by retrofitting of existing buildings. Some pioneering, well-designed and well-known green roofs can be enumerated:

- The first research-experiment green roof was established in 2005 on top of an academic building at the University of Hong Kong.
- A Green Roof for Schools program was initiated in 2007 with donations from a corporation (Hongkong Bank Foundation) to install 14 green roofs. This seed project subsequently triggered more green-roof installations in other schools and non-governmental buildings with the help of government and business funding.
- The largest green roof was established in 2006 on top of the Wetland Park Visitor Centre with a walkable vegetated area of 12,620 m². It is mainly covered by grass with only two rows of landscape trees.
- A large green roof was installed in 2007 on top of a shopping mall called The Elements in a newly developed area (Kowloon West).
- The first rooftop woodland was installed in 2008 on top of an electricity substation in Kowloon.
- The first green roof on top of a railway station was installed in Tai Po in 2009.
- Green roofs were installed in 2010 on top of a new prison in the New Territories, believed to be the first penitentiary facility to have roof greening.
- The first experimental vegetable field was established in 2011 on the roof of the library building at the University of Hong Kong.

- Commercial properties owned by a developer (Hongkong Land) greened the roofs of their shopping malls and footbridges from 2011 to 2013.
- The new government office complex, opened in 2011 at Tamar, included green roofs on top of the Legislative Council chamber and underground parking garages.
- A new sky woodland in conjunction with four massive green walls was installed in 2013 on an electricity substation in a new town (Tseung Kwan O). With high-density vegetation cover, complex biomass structure, diverse species composition and attractive flowers, it offers the finest example of building-envelope greening for an institutional structure in Hong Kong.

Roof farming, biodiversity and environmental education. Source: M. Köhler.

The green roof and associated green wall (vertical greening) research projects were initiated in 2005 at the University of Hong Kong and sustained by generous donations and grants provided by the government and private sector. Thus far, eight sites with field experiment plots and environmental monitoring equipment have been established:

- a green roof on the University's Runme Shaw Building;
- a green wall on the Runme Shaw Building;
- a native woodland on the CLP substation in Lai Chi Kok;
- a large-scale public building of the Tai Po Railway Station;
- a public housing-estate site at Tseung Kwan O;
- a large-scale plant species trial site on the University's Library Building;
- a setup to evaluate hydrological benefits on the Library Building; and
- a large-scale green wall combining environmental assessment and species trial at

the Drainage Services Department's Shatin site. These experiments are well equipped with state-of-the-art environmental monitoring sensors and data loggers to acquire long-term data related to microclimatic, thermal, energy, hydrological and species performance.

The experimental study has been extended to territory-wide assessments based on remote sensing images, geographic information systems, digital image analysis and field work. They cover:

- the urban-fabric factors accounting for green roof distribution;
- the potential sites for green roof establishment;
- the macro-scale benefits in terms of suppressing the urban heat island effect, enhancing carbon sequestration and hence reducing the carbon footprint, curtailing greenhouse gas emission, and trimming energy consumption; and
- a game-theory simulation to find the best strategy to promote green roof adoption.

CHALLENGES OF GREEN ROOF DEVELOPMENT

Some factors have restricted or stifled the development of green roofs in the compact city:

- The humid-tropical monsoon climate with frequent rainstorms and typhoons (wind speed often exceeding 100 km h^{-1}) may damage vegetation on roofs.
- Ample rainfall and warmth in the hot-rainy season from April to September can invite aggressive growth of weeds and other competitors or pests of green roof plants.
- The extended cool-dry season from October to March demands regular irrigation to sustain plant growth.
- The load bearing capacity of many old building is sometimes too low or unknown (due to loss of government records), making it uncertain or risky to install a green roof.
- Some older buildings have not received proper maintenance for too long, resulting in leaking and structural problems to render them unsuitable for green roof installation.
- Many rooftops of commercial buildings tend to be occupied by air-conditioning units, making them unavailable for roof greening.
- The policy framework of some key government departments controlling land, planning and building administration has not been adjusted to facilitate green roof installation.
- Absence of government and industry technical standards and specifications on green roofs.
- Inadequate knowledge and skill level of some green roof contractors.
- Use of low-quality materials by some contractors.

OPPORTUNITIES FOR GREEN ROOF DEVELOPMENT:

Some factors are conducive to the development of green roofs in Hong Kong:

- The city, with a reasonable GDP and per capita income and a healthy governmental financial status, can afford to install green roofs.
- The central level of the government has adopted an enabling attitude to promote green roofs.
- Green roof research findings at the University of Hong Kong have provided ample objective information and support to advocate and win support for green roof innovations.
- Liberal publicity efforts associated with research programs have raised public awareness and community knowledge about green roofs.
- The community has developed an earnest desire to improve the quality of the environment and quality of life through multi-faceted urban greening, including roof greening.

ROOF GREENING STRATEGIES:

The following strategies are proposed to enhance the quantity and quality of green roofs in Hong Kong:

- Improve the relevant technical competency by developing and adopting stringent standards

and specifications of green roof materials and methods.
- Establish an official contractor accreditation and registration system to scrutinize the knowledge and skill of concerned companies.
- Enhance training of green roof engineers and technicians with respect to design, installation and maintenance.
- Accord higher priorities to greening the roofs of old urban areas which are deficient in ground-level green spaces.
- Give preference and support to the greening of roofs on residential buildings.
- Plan new towns or new development areas to insert more green roofs.
- Where appropriate, ensure that the green roofs are easily accessible to the public.
- Support more in-depth research to optimize cost-effectiveness, ecosystem services and multiple benefits of the innovative urban greening technology to the ultra-compact city.

MAIN JUSTIFICATIONS FOR SKYRISE GREENERY IN HONG KONG:

- Evapotranspiration cooling of ambient air especially in the long and hot summer
- Shielding and thermal insulation to reduce heat influx into indoor space
- Amelioration of the urban heat island effect
- Mitigation of the urban smog problem
- Introduction of greenery and natural elements in compact built-up areas
- Provision of high quality green spaces in safe and often secluded locations
- Compensation for the grave shortage of green spaces at the ground level
- Enhancement of urban wildlife and urban biodiversity
- Teaching and learning about nature in schools

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

A research team composed of three postdoctoral fellows, three PhD students and three technicians or research assistants has been established by Professor C.Y. Jim at the University of Hong Kong to conduct in-depth studies on the ecological and environmental aspects of green roofs and green walls.

SOME RECOMMENDED SCIENTIFIC ARTICLE ABOUT GREEN ROOFS/LIVING WALLS IN HONG KONG:

- Jim, C.Y. (2010) *School Green Roof: City Cooler and Cleaner*. Friends of the Country Parks and Cosmos Books, Hong Kong, 180 pp.
- Jim, C.Y. (2010) *Environmental and energy benefits of the sky woodland*. CLP, Hong Kong, 86 pp.
- Jim, C.Y. (2008) Ecological design of sky woodland in compact urban Hong Kong. In: Greening Rooftops for Sustainable Communities. *Green Roofs for Healthy Cities*, Baltimore, MD, pp. 1-15.
- Jim, C.Y. and He, H.M. (2010) Coupling heat flux dynamics with meteorological conditions in the green roof ecosystem. *Ecological Engineering* (Elsevier Science, Amsterdam) 36: 1052-1063.
- He, H.M. and Jim, C.Y. (2010) Simulation of thermodynamic transmission in green roof ecosystem. *Ecological Modelling* (Elsevier Science, Amsterdam) 221: 2949-2958.
- Jim, C.Y. and Tsang, S.W. (2011) Modeling the heat diffusion process in the abiotic layers of green roofs. *Energy and Buildings* (Elsevier Science, Amsterdam) 43: 1341-1350.
- Tsang, S.W. and Jim, C.Y. (2011) Game-theory approach for resident coalitions to allocate green roof benefits. *Environment and Planning A* (Pion, London) 43: 363-377.
- Jim, C.Y. and Tsang, S.W. (2011) Biophysical properties and thermal performance of an intensive green roof. *Building and Environment* (Elsevier Science, Amsterdam) 46: 1263-1274.
- Tsang, S.W. and Jim, C.Y. (2011) Theoretical evaluation of thermal and energy performance of tropical green roofs. *Energy* (Elsevier Science, Amsterdam) 36: 3590-3598.
- Tian, Yuhong, Jim, C.Y. (2011) Factors influencing the spatial pattern of sky gardens in the compact city of Hong Kong. *Landscape and Urban Planning* (Elsevier Science, Amsterdam) 101: 299-309.
- Jim, C.Y. and He, H.M. (2011) Estimating

heat flux transmission of vertical greenery ecosystem. *Ecological Engineering* (Elsevier Science, Amsterdam) 37(8): 1112-1122.
- Jim, C.Y. and Tsang, S.W. (2011) Ecological energetics of tropical intensive green roof. *Energy and Buildings* (Elsevier Science, Amsterdam) 43: 2696-2704.
- Jim, C.Y. (2012) Effect of vegetation biomass structure on thermal performance of tropical green roof. *Landscape and Ecological Engineering* (Springer, New York) 8: 173-187.
- He, H.M. and Jim, C.Y. (2012) Coupling model of energy consumption with changes in environmental utility. *Energy Policy* (Elsevier Science, Amsterdam) 43: 235-243.
- Jim, C.Y. and Peng, Lilliana L.H. (2012) Weather effect on the thermal and energy performance of an extensive tropical green roof. *Urban Forestry and Urban Greening* (Elsevier Science, Amsterdam) 11: 73-85.
- Jim, C.Y. and Peng, Lilliana L.H. (2012) Substrate moisture effect on water balance and thermal regime of a tropical extensive green roof. *Ecological Engineering* (Elsevier Science, Amsterdam) 47: 9-23.
- Tian, Yuhong and Jim, C.Y. (2012) Development potential of sky gardens in the compact city of Hong Kong. *Urban Forestry and Urban Greening* (Elsevier Science, Amsterdam) 11: 223-233.
- Tsang, S.W. and Jim, C.Y. (2013) A stochastic model to optimize forecast and fulfillment of green roof demand. *Urban Forestry and Urban Greening* (Elsevier Science, Amsterdam) 12: 53-60.
- Jim, C.Y. (2014) Heat-sink effect and indoor warming imposed by tropical extensive green roof. *Ecological Engineering* (Elsevier Science, Amsterdam). 62: 1–12.

AREA: INDIA

National organization:
Indian Green Infrastructure Network
No:302 , 9 th main 1st block HRBR layout , Kaylan Nagar .
BANGALORE – 560043 Karnataka . INDIA
Secretary – Vivek Martin +91-9845878126

STRUCTURE AND MISSION:

IGIN is a membership-driven NGO set up with the vision to develop world-class green sustainable cities in India by fostering a network of Professionals, Architects, Government Organizations, Industrialists, Developers, etc., and facilitating discussions as well as spread of education on Green technology and environmental issues. India being such a huge market for infrastructure development and city growth, there is a glaring need for green awareness in the country today.

To bridge this gap and foster our vision we believe that a forum and juncture is needed to educate and create awareness among both professionals and civilians. It is with this drive that we also organized International Green Conference, in association with the World Green Infrastructure Network (WGIN).

The International Green Conference was first of its kind in the sub-continent, encompassing educational programs, workshops on Green Sustainable Technology in India. The conference themed "Re-Think Sustainability" was held in Bangalore, India from November 26 - 28, 2012.

The conference will examine international, regional, and national 'best practices' towards achieving green sustenance. The deliverables will be a set of substantive policy and action-oriented recommendations that will be leveraged through participants drawn from within 10 countries and beyond. Varied and relevant topics like Vertical Gardening, Green Roofs, Storm Water Management, Rain Water Sustenance, Urban Water Management, Green Architecture, etc. was covered in this Conference.

CONTACT:

IGIN: Hema Kumar – Founder – President - +91-9945200332
Vivek Martin – Secretary

HOMEPAGE:

www.iginasia.org

NUMBER OF MEMBERS:

About: 95

CITY PROGRAMS

Being a new organization we also are closely working with many NGOs both nationally and internationally .We are also working on wherein Through IGIN landscape professionals can do certification courses. Talking to experts like architects, landscape architects, green technology experts via LIVE video conferencing about the best green projects designed and implemented by them. IGIN wants to bridge the GAP by bringing the best innovative engineering for the landscape industry, professional education and an internationally-recognized certification system.

CONFERENCES:

International Green Conference. Nov 26-28 , 2012 – Bangalore. India

FURTHER ACTIVITIES:

- Urban Farming Systems
- Roof Top Farming
- R&d On Different Types of Roof Garden and Green Facades.

MEMBERSHIP:

Founding member of IGIN

ACADEMIC RESEARCH INSTITUTIONS

Looking forward and collaborating with Indian horticulture

CURRENT TRENDS (2012-2013):

Economical and inovative green facades and roof top farming

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

- Prof. Chandru
- Santosh Stanley

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

- About 8-10 Mill m² green roofs each year.
- About 40% extensive, 60% intensive roof gardens
- Green facades with climbers, green wall, bio/living walls are growing for the past few years at average of 40- 50 thousand m² per year.

RECOMMENDED NATIONAL WEBPAGES:

www.iginasia.org

Roof garden on parking lots, India, Bangalore. Source: M. Köhler.

AREA: IRAN

National organization:
Office Address: Iranian Green Roof Association (IGRA)
No. 418-3rd Alley-Abiverdi 1-Chamran Blvd
Shiraz – Iran Postal Code: 71946-43519
Phone Number: Office: +98 711 6463445 Fax: +98 711 6463151
e-Mail: info@irangreenroofassociation.ir
President: Aslan Jonoubi
Contact
- President: (aslanjonoubi@khatosafhe.com) (aslanjonoubi@hotmail.com)
- Phone Number : +98 917 118 0553

STRUCTURE AND MISSION:

Iranian Green Roof & infrastructure Association (IGRA) is a non-governmental, non-profit organization; in cooperation with governmental as well as private institutions to promote and construct Green spaces.

As a representative of WGIN, IGRA has registered and established standards and regulations of Green Roof Design in Iran via the city councils. In-order to promote and inspire sustainable attributes we have attended annual most conferences hosted by GHRC worldwide, and have also released presentations as well as articles and have hosted many symposiums and seminars throughout Iran.

We specialize in Green roofs (extensive semi-intensive and intensive), and green walls. Principles of environmental awareness are fundamental to our design culture. Our sustainable solutions have shaped many projects throughout Iran; our projects have achieved honors and recognition for environmental responsibility.

Our capabilities provide for a range of sustainable outcomes; our strategic planners help local governments develop strategies to reduce their carbon footprints. Our economists inform a higher and more even quality of life for communities. Our environmental ecological planners conserve open space, protect biodiversity, restore habitat, support renewable energy development, and manage natural resources. Our master planners create inherently more sustainable communities by encouraging dense, mixed-use development correlated with mass transit, pedestrian connectivity, and open space. Our architects and building engineers deliver high-performance buildings tailored to their contexts. Our landscape architects and urban designers design low-impact landscapes. Our program construction managers maintain and advance sustainable agendas as projects are implemented. We take pride in providing sustainable green roofs. Our technical expertise is backed up by scientific research, therefore our roofs work exactly in the nature it is intended for. We provide the correct system for the exact requirements. We do not design substandard roofs, only installing systems we can guarantee to be sustainable.

ORGANIZATIONS- STRUCTURE:

Non-governmental, non-profit organization

CONTACT:

Aslan Jonoubi

HOMEPAGE:

- *www.irangreenroof.ir*
- *www.shirazgreenroof.ir*
- *www.irangreenroofassociation.ir*

NUMBER OF MEMBERS:

About: 60 members. including: corporate members and Manufactures

CITY PROGRAMS

Alterations about regulations in green roof plans have been approved throughout Iran by city councils via Aslan Jonoubi who's now a policy maker of Incentive programs for the metropolitan in Iran-Shiraz.

Detail of the results:
Executive committee consisting of Civil Service executive, urban planning executive, architecture executive, managing director of parks, and the managing directors of environmental organizations in Shiraz were all involved in a two week discussion about sustainable developments throughout the country; where at-last the city council adopted a project entitled to promote the value of sustainable practice and green development. The City Council approved plans to build new green spaces on buildings and rooftops vertically and horizontally.

Green roof policies
Shiraz's city council has altered building codes and has regulated policies based on Bame Sabz guidelines, which is now the official booklet of Green Roof Standards in Iran.

CONFERENCES:

• *Green Roof Symposium WGIN Shiraz-Iran:* On the 6th of November 2013, a Symposium

ArtPrize 2013. Source: Greenroofs.com. Photo Courtesy of LiveWall.

was held in Conference hall of Fars province telecom and Aslan Jonoubi The representative of WGIN (World Green Infrastructure Network) in Iran was talking Regarding the benefits and technical Issues of Green Roofs and Green Walls. He, as a policy maker of Incentive Program for a metropolitan in Iran-Shiraz, talked about the world experiences of Green Roofs and Green Walls.

• *Engineers Society of Fars Province symposium Conference*
In 2012 a Symposium was held in the Conference hall of Engineers society in the province of Fars regarding Green Roof technical issues and benefits.

FURTHER ACTIVITIES:

- Organized classes to teach Green roof technology through the education of GRHC classes in New York, Atlanta and Toronto.
- Preparing Plant Specification for the purpose of Green Roof within Iran's Climate.
- Promoting Green Roof Benefits through seminars and publications.
- Green facades
- Cost – benefit Analysis of green roofs and green facades.
- Maintenance of green roofs
- Further international cooperation in WGIN
- Inspecting Green roof Designs
- Assembling policy regulations regarding Green Roof Design

MEMBERSHIP:

- GRHC member since 2008
- WGIN Member since 2011

ACADEMIC RESEARCH INSTITUTIONS

Shiraz Azad University

CURRENT TRENDS:

- Green Roof
- Green Wall

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE

Aslan Jonoubi

GREEN PROJECTS:

www.omranparsco.ir
www.mooshircenter.ir
www.eramcenter.ir

AREA: ITALY

National organization:
Headquarters AIVEP - Italian Green Roof Association
Lungotevere degli Altoviti, 4 – 00186 Roma.
Ing. Giorgio Boldini (President).
Current Board of Directors:

- Ing. Boldini Giorgio (president)
- Ing. Fiori Matteo
- Dott. Agr. Rigolli Riccardo
- Dott. Agr. Zecchini Ivano
- Prof. Arch. Panunzi Stefano
- Arch. Bit Edoardo
- Arch. La Rosa Maria Elena
- Dott. Geol. Crasso Maurizio - Harpo s.p.a.
- Perini Livio - Europomice
- Frapoli Stefano – Poliflor Scarl
- Geom. Campagnoli Valter
- Sign. Ra Casolaro Ondina
- Sig.ra Modena Anna Ludovica
- Ing. Comel Silvio

STRUCTURE AND MISSION:

The AIVEP (Italian Green Roof Association) is a non-governmental, non-profit organization that promotes all national activities of green roofs (extensive and intensive), green facades and other technology with greenery-related functions in architecture.

AIVEP - Italian Green Roof Association - was founded in 1997 to:

- Aggregate all those who work professionally and scientifically in the field of green roofs or are interested in the topic of green roofs to combine resources and energies.
- Create synergies in research and dissemination of technical design, implementation and maintenance of green roofs.

AIVEP is a member of the EFB European Federation of National Associations
The Association has the following objectives:

- disclosure of the technical realizations of green roof professionals. These techniques constitute the modern discipline that applies, in a scientifically-sound manner, the most innovative methodologies to achieve and maintain a stable green roof on different types of roofing, consistently with the standard UNI 11235: "guidelines for the design, execution, inspection and maintenance of green roofs";
- qualification of green roofs;
- awareness of the central and local institutions; adoption of new resolutions and directives that encourage the development of green roofs; application of the existing rules;
- creating links with other associations that work to protect the environment and the development of green infrastructure.

Members

Since this is a cross-discipline that uses data and knowledge from various scientific and professional members, AIVEP belong to different professions and sectors:
Agronomists, architects, forestry industry, engineers, landscape architects, technicians, systems manufacturing companies, companies producing components running specialists, nurserymen, gardeners teachers, public and private institutions, environmentalists and nature lovers.

CONTACT:

Dr. Riccardo Rigolli
mail@rigolli.com

HOMEPAGE:

www.aivep.org

CITY PROGRAMS

Law 10/2013: "Regulations for the development of urban green spaces"
CEN - European Committee for Standardization: CEN/TC 390 "Project Committee – Criteria for design, performance, test methods and maintenance of roof gardens".
Presidential Decree No. 59 of 2/6/2009 - "Regulations on the implementation of Article 4, paragraph 1, letters a) and b) of the DLG 19 August 2005, n. 192, concerning the implementation of Directive 2002/91/EC on the energy performance of buildings. "
R.I.E. Index - Building's impacts index
http://www.lexambiente.org/acrobat/strumurb.pdf

CONFERENCES:

http://www.nemetonmagazine.net/blog

FURTHER ACTIVITIES:

Current working groups:
Two departments are active in the association for purposes of aggregation and coordination:
- Research section
- Businesses section

Bougainvillea is one favorite climber. Lago di Garda (Italy). Source: M. Köhler.

GROUP COMPONENTS

Group 1 - Web info. Boldini - Comel - Rigolli
Group 2 - Law of Urban Green Infrastructure. (General coordination activities - preparation of AIVEP documents - proposals Conferences and territorial). Boldini - Casolaro - Crasso - Fiori - Panunzi - Perini - Rigolli
Group 3 - Law professionalism unregulated. (Information requirements at the Ministry - coordination, organization and proposals). Boldini - Casolaro - Crasso – Zecchini
Group 4 – Interior. (Bylaws, rules of procedure, qualifications and commissions - financial - UNI updates – analysis composition AIVEP). Casolaro - Modena – Zecchini
Group 5 - Innovation Cloud. (Analysis and evaluation of participation). Panunzi

MEMBERSHIP:

Founding member of EFB, Founding member of WGIN?

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

See Bibliographic information.doc

CURRENT TRENDS (2012-2013):

- Urban farming
- Vertical greening

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

- Prof. Stefano Panunzi
- Dr. Riccardo Rigolli

RECOMMENDED NATIONAL WEBPAGES:

- http://www.nemetonmagazine.net/
- http://www.promoverde.it/
- http://www.verdeepaesaggio.it/
-https://www.facebook.com/portaleprogres?sk=wall
-https://www.facebook.com/Associazione.Arspat
- Guidelines: UNI 11235:2007. ISPRA

AREA: ISRAEL

National organization:
Israel Green Building Council
www.ilgbc.org

The council acts according to principles of sustainability that balance environmental, social and economic interests. It works towards being positioned as a leading and up to date organization in the field of green building. It strives for internationally recognized high standards which are adjusted for the local conditions.
Working with the Ministry of Environmental Protection, the SII and leading academic institutions, the ILGBC also helped to establish the framework for accreditation of green building professionals. To date 120 professionals have already received accreditation to work with the revised standard.

CONTACT:

Fran Sorin
Author of *Digging Deep: Unearthing Your Creative Roots Through Gardening*, Ecological Landscape Design Specialist
fran.sorin@gmail.com, FB, Twitter, LinkedIn

CITY PROGRAMS

Tel Aviv

More than 100 buildings and towers in the Tel-Aviv, Yaffo district are built according to the principles of Green Building.
Since 2011, Tel Aviv has implemented the element of Green Building and is making it an obligation for the parties involved in the development and building.
From the year 2012, it is an obligation for involved parties to conform to the new *Israeli Green Building standard*.
In the plans for building construction and design, Tel Aviv approved of a 1,000,000 square meter building for business and residential purposes under the Green Building standard. They are also working on similar projects for the West Tel-Aviv and Sde Dov (the small airport off of the port) area – how to transform an existing neighborhood into a sustainable neighborhood – more community and organizationally oriented.
The Local Planning and Building Unit Tel-Aviv – Yaffo, last year approved an update on instructions on how to plan and implement Green Building within the city. This was done in order to match the existing municipal guidelines of the New Israeli Standard for Sustainable Building that was published in the end of the year 2011 and was fixed by British consultants and multiple Israeli professionals. These guidelines will apply to all types of buildings within the city – in residential buildings the process will be gradual – at this point targeted at high rises (buildings that consist of 9 floors and above). Commercial buildings consisting of more than 20 floors and residential buildings consisting of more than 30 floors will have to submit to more specific Green Building standards (2 stars according to the new laws). These laws will also be implemented on buildings that are being redone through the new Tama 38 process (renovating old buildings while adding on extra floors).
It has also been decided that public buildings will have infrastructure for green roofs and solar

energy panels as a standard. The City Hall politicians have voted in favor for these new regulations.

In the past year and a half, 170 buildings in the city were built within the new Green Building regulations (a totla of 1,000,000 meters of commercial, residential, hotels and public buildings). In addition the principles of sustainable and green building are to be assimilated as a standard for architectural and city planning for Tel-Aviv.

Every education building within the city will have to assimilate Green Buildings standards (19 kindergardens, 8 schools and 5 sports centers).

Schools with sea views with in the "Goosh Hagadol" will be built with extremely high Green standards and was chosen as the first school in the country that will have a "green tag" according to the new standards. The school will be built according to the principles of Green planning and building with the guidance of a Green Expert and will be held to standards such as energy saving (shade, infrastructure, natural light, etc), water usage reduction and will be imbedded with solar system on the roof and put emphasis also on recycling. There will also be a green garden and an ecological structure on the roof of the school.

In the year 2008, a agreement was signed with Tel-Aviv, Yaffo and 15 city forums to reduce gas and environmental pollution and warming. In a statistic testing it was found that 67% of the air pollution is produced by structures (mostly energy used within these structures). Because of this in April 2011, it was passed that new construction will need to receive a permit according to their use of the Green Building principles. These guidance principles deal with saving energy, water, use of healthy building ingredients, improvement of tenant health (natural light, healthy air). These will need to be met in order to receive a building permit.

Google campus, Tel Aviv

"In 2013, Google moved into a new office space in Tel Aviv, Israel. Designed by Camenzind Evolution, in collaboration with Setter Architects and Studio Yaron Tal, the impressive 8,000 sqm campus occupies 8 floors in Electra Tower.

It is a new milestone for Google in the development of innovative work environments: nearly 50% of all areas have been allocated to create communication landscapes, giving countless opportunities to employees to collaborate and communicate with other Googler's in a diverse environment that will serve all different requirements and needs.

Only 7 of the 8 rented floors in Electra Tower are actually occupied by Google. The remaining floor gives space to a new 'Campus', which was also opened in December by the Israeli Prime Minister. The 'Campus Tel Aviv', powered by Google for Entrepreneurs, is a new hub for entrepreneurs and developers, providing a base for start-up companies, and is only the second Google 'Campus' worldwide.

Sustainability played a vital role to Google in the development of their new Tel Aviv offices and the project is currently awaiting LEED 'Platinum' certification, the first of its category in Israel."

Source:
http://officesnapshots.com/2013/01/31/google-tel-aviv-office-design/

Jerusalem

"The Jerusalem Municipality has put photo-voltaic cells the roofs of 100 schools, in East and West Jerusalem. Money earned from saved electricity is invested in environmental education.

One Jerusalem school in West Jerusalem has a green roof, and a second special-ed school in East Jerusalem is about to have one. In addition, the Jerusalem Bird Observatory has a Seasonal Living Roof and Walls.

Jerusalem has a flourishing network of 45 community gardens, much loved by the diverse communities of the city.

Neighborhood recycling centers have been placed in community gardens, which have become a hub for community activities. In the last 3 years, recycling has increased from 2% - 14% in Jerusalem.

Because of Jerusalem's steep hills, rainwater -

harvesting is coming back into regular practice, as it was in ancient times. Urban landscaping is increasingly making use of drainage basins to create natural lakes, retain water for nature and prevent flooding.

Jerusalem is blessed with an abundance of Urban Nature. An in-depth report conducted by the Society for the Protection of Nature in Israel surveyed 151 sites.

Jerusalem's urban nature sites are all to be found on the city's green map (www.greenmap.org.il)

Within the ICLEI-LAB initiative, Jerusalem is the only city in the Middle East that has prepared a Local Biodiversity Strategy and Action Plan. This initiative ensures that nature in Jerusalem will be afforded the respect of an independent and critical layer of infrastructure, not simply what is left over after urban development.

The Gazelle Valley is a pioneering initiative which began as a grass roots campaign, but has developed into Israel's first urban nature park (60 acres)

Jerusalem is the first city in Israel to put in Light Rail, which has taken all polluting traffic out of the city."

Contributed by Naomi Tsur, Ex -Deputy Mayor of Israel, has been a major force in helping these Jerusalem projects come to fruition. She has recently left the ministry to devote more time to her role as President of Green Pilgrim Jerusalem. (www.greenpilgrimjerusalem.org)

Haifa

In Haifa "Intel Israel" dedicated the country's most environmentally-friendly office building. Dubbed IDC9, the 11-storey, $110 million facility has a double distinction. It is Israel's first LEED-certified green building and it has been awarded Gold – the second-highest rating in the LEED certification system.

There are barely a handful of LEED-certified buildings in Israel.

The facility incorporates a slew of green elements, beginning at the construction level. Construction waste was separated at source into its component parts and recycled. About 13 percent of the construction materials came from recycled sources. The structure was constructed on a previous parking site to prevent damage to natural assets. These measures are expected to result in a reduction of 17% in total energy consumption.

In addition, an energy-saving technique has been used in the facility's server room. Spread over 7,535 square feet, the space will house up to 15,000 computers. The heat generated from these computers will be recycled for hot water

The Golisano Institute for Sustainability. Source: Greenroofs.com. Photo Courtesy of Green Living Technologies International (GLTi).

and winter heating. The room uses energy-efficient lighting and is equipped with motion detectors that turn off the lights when it's not in use. The building's data center has also been designed to save energy. It features Intel Xeon processors, which reduce power consumption.

The building boasts wide and double glazed windows, patios and reflective shelves, which allow natural light to filter inside. More than 75% of its high-use areas are exposed to natural light with the help of automatic control systems that regulate the flow. Automatic sensors control the levels of artificial lighting according to the natural light, and employees can control lighting and temperatures in their offices via their personal computers. Fresh air is monitored by CO_2 sensors that track the number of people on each floor.

The roof of the facility is covered with vegetation and heat-reflecting materials to lower interior temperatures. The roof garden provides enough thermal insulation to lower the heat load by 17 cooling tons. A special control system installed in the facility reduces water consumption for gardening needs by 55%, compared with average summer consumption. Water condensed by air conditioners is collected and used for gardening. The facility has also installed standard water-saving sanitary systems such as faucets, showers, toilets and urinals to achieve 30% reduction in water usage."

Information taken from Israel21c.org - http://israel21c.org/environment/intel-israel-goes-green-and-wins-gold/

K'far Saba

K'far Saba is planning a "green revolution," with a comprehensive plan for numerous short-term and long-term changes.

In the near future, the city plans to change all street lights to energy-conserving bulbs, work with shopping centers to reduce the use of plastic bags, use recycled paper in all municipal offices, change municipal inspectors' uniforms to ones made of recycled material, encourage the use of "clean" energy, conceal electrical transformers underground and take other steps. In the long term, the city plans to create an environmentally-friendly farm on the agricultural land in the east of the city, check the possibility of using hybrid fuels in public transport, and introduce a pilot program for newspaper recycling that will see special bins placed around the city, much as bottle-collection bins are placed now.

The report said the "jewel in the crown" will be Kfar Saba's new "green neighborhood" in the west of the city, the first in Israel to be built according to green guidelines that include improved thermal insulation and other measures designed to save electricity, solar power systems, water-saving equipment, a unique underground garbage removal system, and numerous pedestrian and bicycle paths.

A municipal spokesman said that even though building work on the "green neighborhood" has not yet begun, demand for apartments in the project has been high. Kfar Saba mayor Yehuda Ben Hamo said it was also the city's intention to work with local businesses to encourage them to take steps toward improving the environment.

The plan was put together by councilors, municipal officials and representatives from the Ministry of Environmental Protection."

Information taken from : http://www.jpost.com/servlet/Satellite?cid=1192380709937&pagename=JPost%2FJPArticle%2FShowFull

STRUCTURE AND MISSION

A Leading Israeli Sustainable Architecture Firm: *Knafo Klimor Architects* (http://www.kkarc.com)

Knafo Klimor Architects, founded by David Knafo and Tagit Klimor in 1980, operates from 2 branches in Tel Aviv and in Haifa with a diverse staff including architects, urbanists and designers.

They designed the Green Elementary School in K'far Saba, the first green school meeting LEEDs standards, which was completed in 2012.

This design has been so well received that the

firm has already been commissioned to build another green school.
For more information on the project, click on: http://www.kkarc.com/projects.aspx?gp=3&c=444&p=3781

ACADEMIC INSTITUTIONS:

Last year, Haifa University built a green roof and ecology center - A statement from Haifa University declared, "Until now, Israel has not had a research center for green roofs and research from other countries has not necessarily been applicable for the unique climate and flora of the Middle East. The new center, headed by Prof. Leon Blaustein of the University's Department of Evolutionary and Environmental Biology, will be examining the field in the Israeli context: Will it be possible to assemble green roofs in the Israeli climate without artificial irrigation? Will Israeli flora be reliable to serve for green roofs; and do green roofs increase the biological diversity of insets and plants?"

Tel Aviv University's Porter School of Environmental Studies

A new building at Tel Aviv University features a standalone EcoWall that aims to provide vertical garden space and research facilities for its faculty. The university's Porter School of Environmental Studies (PSES) hopes that its new green building design will not only join the small number of LEED certified buildings in the country, but will also highlight sustainable methodologies for future buildings in Israel. The 3,700 sq m (39,826 sq ft) building will also use a cost-effective chilled beam cooling system that works by circulating interior and outdoor air through mounted chilled water coils and then redistributing it back into the space to regulate the temperature.
The EcoWall and green roof of the building will become a sustainable architecture research lab, and both will play a central role in ongoing energy, water, soil, vegetation and materials studies at the university. Additional sustainable features include 50kw solar panels, biological pools and grey water harvesting that will prove vital in this drought-prone region. Environmental data gathered by the school will be displayed on the egg-shaped capsule meeting room that extrudes in both directions from the EcoWall. With only three other LEED-certified buildings in the country, PSES hopes to achieve LEED platinum status upon completion later this year."
Source: Axelrod-Grobman Architects via ArchDaily
Sourced from: http://www.gizmag.com/pses-tel-aviv-sustainable-building/28080/

AREA: JAPAN

National organization:
Landscape and Urban Green Infrastructure
Kanda Jinbocho,3-2-4, Tamura Build. 2F
Chiyoda-ku, Tokyo, 101 0051
Tel +81 352167191 Fax +81 352167195

MISSION OF THE NATIONAL ORGANIZATION:

The first international horticultural exposition in Asia "The International Garden and Greenery Exposition" was held in 1990. The philosophy behind this exposition was to capture the relationship between flowers, greenery and man in his/her daily life and thus look toward creating an affluent and comfortable society in the 21st century. The Organization for Landscape and Urban Greenery Technology Development (abbreviated as Urban Green Tech.) was set up in November 1990, to continue developing the philosophy inherited from that exposition. The role of Urban Green Tech, is to act as a coordinator, bringing together public policies, technology from the private sector and knowledge from the academic world, and through research and development into the latest scientific techniques relating to the greening of towns and cities, achieve its objective of contributing to the creation of pleasant cities using an abundance of greenery. Since 2013, the organization name has been changed to "Landscape and Urban Green Infrastructure" due to adding soft activities such as furthering the dissemination of technology and ideas.

Structure:

An expert is stationed as the chairman, a chairman of the board of directors, six directors, six councilors, two inspectors, secretariat personnel, three administrative divisions, two planning departments, investigation, and a research section. The chairman, a chairman of the board of directors, and a representative director are elected from private enterprises, a government-affiliated organization, and academic circles. The term of office is generally two years. The present chairman is Mr. Ryo Yano: Sumitomo Forestry Co., Ltd., Chairman, and the chairman of the board of directors is Mr. Hajime Koshimizu; Professor of Meiji University.

ORGANIZATIONS STRUCTURE:

Foundation, non-profit, non-government organization

CONTACT PERSONS:

Hajime Koshimizu

HOMEPAGE:

http://www.urbangreen.or.jp

E-MAIL:

midori.info@urbangreen.o.jp

MEMBERS:

It consents to the meaning of activity of an urban-greening mechanism, and is looking for anyone who can provide support as a member. As for supporting members, the ON meeting accepts anyone regardless of the individual, the corporation, or the organization. An application is accepted at any time. Present membership is 40 companies.

NATIONAL PROGRAMS:

Urban green space laws say that in the region of greening, facilities with green roofs receive a reduction of up to one-half of the property tax. There is a system of solid parks. A park can be built on the roof of a business complex or the artificial ground of a commercial establishment. Management of this space is transferable to a local self-governing body. The local self-governing body can install a park, without acquiring land. Tokyo and cities with a population of 1 million or more have ordinances which impose a duty on the rooftop gardening or greening to a new-building. It is required to green 20% of development sites, and it is assumed that the roof will be sufficiently green. Tokyo is an example that a fine is imposed when this ordinance is broken. The number of local governing bodies that have such an ordinance has increased since the early 2000s and green roof area has increased rapidly. Support from municipal corporations to greening costs is 20,000 yen/m^2 with a maximum of 2 million yen.
Research meeting and individual conferences: There are six study groups in the organization and additional companies besides members have also participated. Investigations are being performed about the promotion of maintenance, research and development of rooftop gardening, including technical development, aimed at spreading information about a disaster-prevention park. The aim is to recommend planning for earthquake-prone cities. For river shore protection, the characteristic of groundcover plants for advancing tree planting of parking lots and schoolyards is being investigated. The aim is to develop plating technology so that people with disabilities or elderly people can live safely. There are projects aimed at spreading activities for developing universal design and gardening programs in urban space and another project aimed at exploring the domains, which should tackle a new century.

Source: Hajime Koshimize.

FURTHER ACTIVITIES:

Research, study and technological development, evaluation technologies, technological development through dissemination, support for research studies, furthering the dissemination of technologies.

ACADEMIC RESEARCH INSTITUTIONS:

- Tokyo University: www.u-tokyo.ac.jp/index_j.htm
- Chiba University: www.h.chiba-u.ac.jp
- Meiji University: www.meiji.ac.jp
- Tokyo Agriculture University: www.nodai.ac.jp
- Oosaka Prefectural University: www.osakafu-u.ac.jp
- Awaji Landscape and Horticultural School: www.awaji.ac.jp

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

- Journal of Japanese Institute of Landscape Architecture
- Journal of Japanese Society of Revegetation Techonology

- Journal of Japanese Society of Turfgrass Science
- Urban Green Tech.

RECOMMENDED NATIONAL WEBPAGES:

www.mlit.go.jp/toshi/index.html

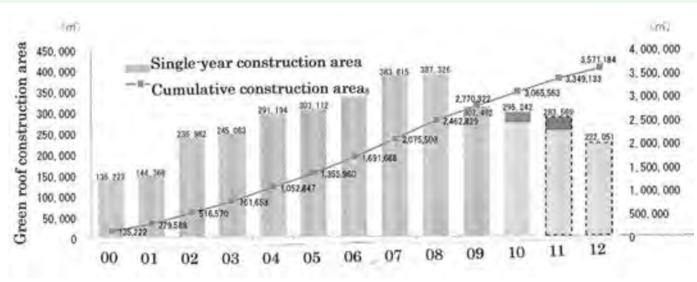
ADITIONAL INFORMATION:

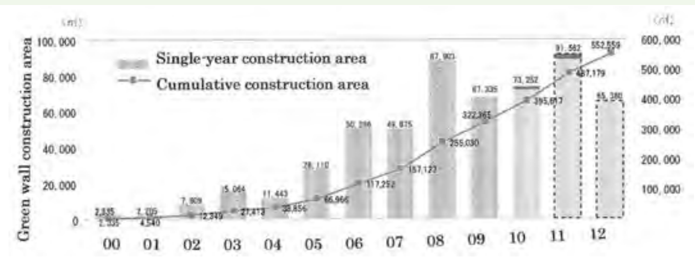
The graph shows the change of the green roof construction area (m^2) in Japan from 2000 to 2012. The reason why the construction area was decreased in 2009 later, term of execution of subsidy in the national government was over. After this, the government subsidies began to shift to solar power on the roof. But construction area has maintained the level of 2002. Total area of the green roof is still increasing.

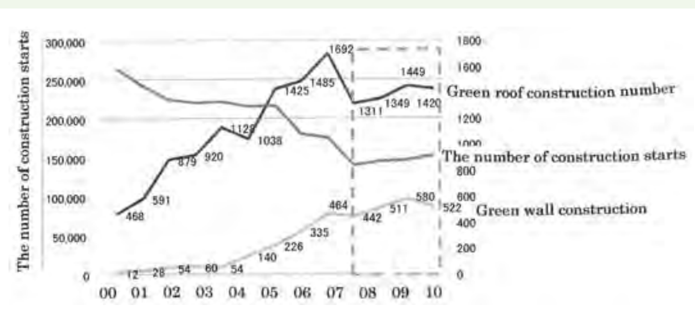
The graph shows the change of the green wall construction area(m^2) in Japan from 2000 to 2012. In comparison with the trend of green roof, construction area of the green wall has not increased clearly until 2004. The reason why the area or the green wall is increased, where construction is not only building, where construction site has been expanded, such as the courtyard entrance and retaining wall of the elevated railway, multi-storey car park and a large-scale commercial facility. Area of green walls since 2005 has increased more rapidly than green roof. However footprint of each year has fluctuated. Green walls are provided in commercial facilities. The number of construction of commercial facilities every year has been subtly influenced by the economy condition from time to time.

The line graph shows the change in the number of construction green wall, green roof and the number of building construction starts in Japan from 2000 to 2010. The number of building construction gradually decreased by 2007. Since 2008, the economy is picking up somewhat, the number of building construction is starting to increase. With the recovery of the economy, since 2008, a downward trend of construction number of green wall and green roof has stopped. Only economic trends rather than the reason of booming construction, but the society or people began to seek the urban space with the beautiful and comfortable atmosphere with green.

GROWTH OR CHANGE OF GREEN ROOF AND GREEN WALL IN JAPAN







AREA: **KOREA**

National organization:
Korea Green Roof & Infrastructure Association (KOGRIA)
Science Hall 1. Landscape architecture lab. #207.
Seoul Women's University
Seoul, Korea.
Phone number : +82-2-970-7675
Fax : +82-2-970-5950

STRUCTURE AND MISSION:

Cooperation among governmental as well as private organizations, research institutes, educational institutions, and green roof companies for the Construction of Urban Green Space in the Future

Our association consists of relevant governmental as well as private organizations, research institutes, educational institutions, and private companies for green space. At first, we came together to discuss the issue of the Urban Green Space Project, aiming to change our desolated city filled with grey concrete into a lively one with greenery. Then, we reached a conclusion: Research and development for the advanced green technologies and their distribution are the most realistic as well as idealistic solutions.

In an effort to find the best ways to proceed with it, we organized the "Association for Study of Green Roofs," and released many presentations as well as articles for Roof Greening periodically. Additionally, we hosted lots of symposiums and seminars, inviting relevant professionals to introduce the needs of roof greening systems, the technologies as well as methods, and good examples of it.

With our continuous activities, research and studies of the Green Roof Project, we finally officially established the Korea Green Roof & Infrastructure Association (KOGRIA) with the authorization of the Ministry of Environment on Jan, 2003. Since then, KOGRIA has constantly tried to create new urban green spaces based on the outcomes and experiences gained through our studies.

ORGANIZATIONS- STRUCTURE:

Non-profit, non-government organization

CONTACT:

- President : Prof. Eunheui, Lee (Unhi Lee) (ehlee@swu.ac.kr)
- Executive secretary : Heejung, Youn (cornus@swu.ac.kr)

HOMEPAGE:

http://www.ecoearth.or.kr/

NUMBER OF MEMBERS:

150 single members and 36 corporate members from all related professions of green infrastructure.

Corporate members: See the details of the list from Dec. 2012: http://www.ecoearth.or.kr/pds/company_info.htm

CITY PROGRAMS

- Academy for green roofs (water proofing, design, management): Seoul, 2003
- Workshop: Green Wall (Living Wall): Busan, 2008
- Annual Green Space Fair (Since 2010)
  - The 1st Green Space Fair: Feb. 2010 (Gangnam-gu office, etc.)
  - The 2nd Green Space Fair: June 2010 (Busan city hall, etc.)
  - The 3rd. Green Space Fair: Oct. 2011 (SBS broadcasting company, etc.)

Busan City Hall green roof

• The 4th. Green Space Fair: Oct. 2012 (Daewoo 'purugio' green space in Bucheon, etc.)

FURTHER ACTIVITIES:

- Every 2 years, Green-roof Technology Seminar of Korea and Japan : since 2004 in Seoul
  • The 1st Green-roof Technology Seminar of Korea and Japan (in Seoul, Korea, 2004)
  • The 2nd Green-roof Technology Seminar of Korea and Japan (in Tokyo, 2006)
  • The 3rd Green-roof technology Seminar of Korea and Japan (in Seoul, 2008)
  • The 4th Green-roof Technology Seminar of Korea and Japan (in Tokyo, 2010)
  • The 5th Green-roof Technology Seminar of Korea and Japan (in Seoul, 2012)

MEMBERSHIP:

WGIN member since 2011

ACADEMIC RESEARCH INSTITUTIONS:

- Seoul Metropolitan Government (supports green roof projects since 2002)
- Seoul Women's University, Prof. Eunheui, Lee (mitigation of urban heat islands and air pollution with green plants and green roofs, a planting model of extensive green roof systems, effects of an extensive green roof system on rainwater circulation, urban horticulture, etc.)
- Dongguk University, Prof. Choonghyun, Oh (urban horticulture and green roofs, etc.)
- Seoul National University, Prof. Dongkun, Lee (mitigation of urban heat islands and restoration)
- Sangmyung University, Prof. Taehan, Kim (thermal simulation of extensive green roof systems, solar energy systems)
- Korea Institute of Construction Technology, Prof. Hyunsu, Kim (green walls, technology for developing eco-housing estates that countermeasure urban climate changes)
- Gyeonggi Green & Agriculture Foundation (supports green roof projects in Gyeonggi, landscape gardening program)

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

Prof. Eunheui, Lee
- A Study on Competitive Relationship of Ground Cover Plants for Artificial Roof Greening, 2010
- Effects of Extensive Green Roof System on Rainwater Circulation, 2011

Prof. Hyunsu, Kim
- Resistance to Root Penetration of Root Barrier for Green Roof System, 2008
- Technology on developing eco-housing estate that countermeasures urban climate changes, 2010

CURRENT TRENDS:

Urban agriculture on roofs, community roof gardens, mitigation of urban heat islands

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

- Prof. Eunheui, Lee (Seoul Women's University; summarized overview in: Lee, EH., 2009: World Green Roof Infrastructure Congress, Toronto)
- Prof. Hyunsu, Kim (Korea Institute of Construction Technology)

RECOMMENDED NATIONAL WEBPAGES:

- http://www.seoul.go.kr/info/organ/subhomepage/green/index.html
- http://www.kict.re.kr/eng/rsch/build.asp
- http://www.ggaf.or.kr/eng/business/business_000.html

AREA: MEXICO

National organization:
AMENA A.C.
Asociación Mexicana para la Naturación de Azoteas, A.C.
Calle Uxmal 117-402 Col. Narvarte
C.P.0320, México D.F.

STRUCTURE AND MISSION:

AMENA A.C. is a non-governmental and non-profit organization. It was founded in 2005 by Tanya Müller García and Gilberto Navas Gómez as non-profit association for research, promotion and assessment of public policies to promote green roofs in Mexico.

CONTACT:

Dr. Gilberto A. Navas Gómez.
gnavas.amenamex@gmail.com

HOMEPAGE:

http://www.amenamex.org

CITY PROGRAMS:

AMENA actively participated in the development of the first Norm for Green Roof Installation in a Latin American country. This norm establishes technical specifications for the installation of naturation systems in Mexico City, and was published in December 2008.
Incentives for green roofs range between a 10 and 15% reduction of property taxes.

CONFERENCES:

The first World Green Roof Congress in Latin America was organized in 2010 in Mexico City.
Approx. 500 participants
International speakers with emphasis on Latin American speakers as well as Mexican presenters
25 booths with national and international companies.

FURTHER ACTIVITIES:

International cooperation in WGIN

MEMBERSHIP:

Founding member of WGIN

ACADEMIC RESEARCH INSTITUTIONS:

- Universidad Autónoma Chapingo. http://www.chapingo.mx
- Universidad Nacional Autónoma de México
- Facultad de Arquitectura del Paisaje. http://www.arquitectura.unam.mx
- Instituto de Biología. http://www.ib.unam.mx/
- Colegio de Postgraduados. http://www.colpos.mx
- Universidad Autónoma Metropolitana. http://www.uam.mx/

CURRENT TRENDS (2012-2013):

Green roofs with biodiversity designs
Living walls implemented by companies as showcases.

Roof garden on the castle of Chapultepec in Mexico City. Source: M. Köhler.

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

- Tanya Müller García
- Gilberto Navas Gómez
- Jerónimo Reyes Santiago
- Raymundo Herrera Ortiz

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

About 10,000 m^2 green roofs each year
About 80% extensive, 20% roof gardens
Most of the green roofs are located in Mexico City, Guadalajara and Monterrey. Furthermore, the surface area is difficult to estimate in other cities and smaller towns of the country. But it is Mexico City that leads the development and promotion of green roofs at a national level due to its installation norm which is based on the FFL standards, as well as the fiscal stimulus program. Mexico City also has several projects for the installation of green roofs in public buildings such as schools and hospitals.

Living walls are starting to become popular despite being rather expensive and having to cope with problems with proper selection of vegetation for external walls, water management in relation to evapotranspiration and application of nutrients.

AREA: PERU

National organization:
Agricultura Urbana Perú
Av la Universidad s/n. Lima.- La Molina
Ing. Saray Siura Cespedes, President.

STRUCTURE AND MISSION:

Agricultura Urbana Perú is a nongovernmental nonprofit organization, formed mainly by teachers of various specialties from La Molina National Agrarian University and other universities in the interior, as well as companies. It seeks to promote all national activities related to using available spaces where it is possible to develop agricultural activities and spaces that are located within urban and suburban areas of cities. The purpose is to improve the environment, generate additional sources of income and supply food to families.

- President: Saray Siura Céspedes. (Agriculture - Horticulture)
- Vice President: Jose A. Palacios Vallejo (Agronomy-Ornamental Plants)
- Treasurer: Rosario Pérez Liu. (Economics - Agricultural Economics)
- Member 1: Vilma Gomez Galarza (Economics - Business Management)
- Member 2: María Inés Gorriti (Fishery - Management)

CONTACT:

Dra. Vilma Gómez Galarza
e-mail: vgg@lamolina.edu.pe

HOMEPAGE:

http://www.lamolina.edu.pe/agronegociosvirtual/

NUMBER OF MEMBERS:

- 5 teachers from UNLAM
- 3 teachers from UNCP

CITY PROGRAMS:

- Feed Urban Agriculture for Human Settlements in the Rimac. The FAO and the Municipality of Rimac have developed a draft Urban Agriculture plan in order to guarantee food for 370 families in marginal areas.
- Global agenda: Urban orchard a table - Fstt. From 2005 to 2008 the Cities Farming for the Future Program was implemented. They worked on capacity building among local authorities and other local stakeholders regarding urban agriculture and policy formulation and strategic planning for urban agriculture in a multi-faceted form. http://www.ipes.org/proyecto/43.
- My Huerta Program Urban Agriculture, led by the Metropolitan Municipality of Lima. http://www.munlima.gob.pe/limaambiental/agriculturaurbana-presentacion

FURTHER ACTIVITIES:

San Miguel Municipality (Metropolitan Lima). Promotes recovery ceilings in its jurisdiction. http://www.munisanmiguel.gob.pe/2012/04/municipio-promueve-la-recuperacion-de-techos-en-san-miguel/
Several companies provide services and advice on issues related to improvement and sustainable practices.

ACADEMIC RESEARCH INSTITUTIONS:

- Universidad Nacional Agraria La Molina – UNALM. http://www.lamolina.edu.pe/
- Universidad Nacional del Centro –UNCP. http://www.uncp.edu.pe/
- Asociación Peruana de Arquitectura del Paisaje. http://paiperu.org/

EMPRESAS

Libelula. Green Roof. A natural garden on your roof. http://libelula.com.pe/ ; http://libelula.com.pe/Techo-Verde,977.html
- ARVE. Create landscaping projects with a special and different twists. Their goal is to create new and better green areas in cities. http://globus.pe/peru/arve-jardines-verticales-y-techos-verdes/
- Arqseed Studio Architects. http://www.arqseed.com/techo-verde.html
- Maruplast Internacional E.I.R.L. Leader in the import of plastic products for the horticulture sector. http://www.maruplast.com/techo_verde.html
- Techo Verde Perú. Specializes in the marketing of world class goods and services. http://techoverdeperu.com.pe/web/
- GANIA. Green roofs and walls for charge cities. http://gania.pe/
- Comercial Industrial Delta S.A. (CIDELSA) http://www.cidelsa.com.pe/esp/techos-verdes.html
- Eco- Efficiency and Renewable Energy (CIPER). http://www.ciperperu.com/servicios.html.

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

- Roberto Claros Cohaila, Isabel Claros Abarca (2011). Urban agriculture in municipal agendas. http://blog.pucp.edu.pe/item/143987/la-agricultura-urbana-en-las-agendas-municipales
- Urban and peri-urban agriculture in

Green Roof. Source: Greenroofs.com. Photo Courtesy of Vitaroofs International Inc.

Metropolitan Lima: a strategy to fight against poverty and food insecurity (Third Inter-Agency Meeting). 25 and August 26, 2006, Lima - Peru. Published by the International Potato Center (CIP), the coordinating body of Urban Harvest. http://www.cipotato.org/publications/pdf/004205.pdf
- Noemi Soto y Saray Siura. (2007) Panorama of Experiences of Urban Agriculture in the City of Lima. IPES-Promotion of Sustainable Development. http://www.ipes.org/backup_eyresis/public_html/au/switch/Pdf/Panorama%20de%20Experiencias%20AU.pdf
- Alfredo Rodriguez, UNALM. Green Roof at home.
http://www.lamolina.edu.pe/hidroponia/Boletin62/repotarje%20Publimetro.pdf
- Municipality of Jesus Maria. Jesus Mary Green City. (2013). http://www.munijesusmaria.gob.pe/pdf/publicaciones/jm_verde.pdf
- The Metropolitan Environmental Agenda. http://www.munlima.gob.pe/limaambiental/images/archivos/agenda-ambiental-metropolitana.pdf

CURRENT TRENDS:

- Urban and peri-urban agriculture in popular neighborhoods of Lima and Huancayo
- Strengthening education issues and sustainable economic activities
- Climate change
- Environment

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

- Local Authorities: provincial and district mayors
- University teachers and researchers
- Companies that provide ecological services

lat in relation to evapotranspiration and application of nutrients.

RECOMMENDED NATIONAL WEBPAGES:

– Recover connecting people with nature and a green culture spread from our cities http://peru.panda.org/mi_ciudad_verde.cfm
– Urban agriculture (UA) includes the production and/or processing of harmless agricultural species (vegetables, fruits, medicinal plants, etc.) and raising small animals for consumption..http://www.ipes.org/area/agricultura-urbana
– Peruvian Council for Sustainable Construction. http://www.perugbc.org.pe/site/index.php

AREA: PORTUGAL

National organization:
Continuum Naturale
University of Évora/Management Department
Largo dos Colegiais, 2
7002- 554 Évora

STRUCTURE AND MISSION:

Continuum Naturale was founded in order to coordinate and develop technical, scientific and entrepreneurial efforts oriented toward an improvement of nature integration in urban and rural environments; to encourage, coordinate and facilitate the investigation, teaching, advice and diffusion of all aspects related to the improvement of nature integration in urban and rural areas; and to promote the development and improvement of techniques and practices used in the improvement of nature integration in urban and rural areas.

Board of Directors
- Chair: Maria Raquel Lucas (Management)
- Co-chair: Isabel Joaquina Ramos (Landscape, Environment and Planning)
- Treasurer: Rui Manuel Fragoso (Management)
- Ordinary Member1: Maria da Conceição Freire (Landscape and Planning)
- Ordinary Member2: Maria da Saudade Baltazar (Sociology)

There is also a General-Assembly and an Audit Committee, both composed of three members.

ORGANIZATIONS STRUCTURE:

Non-profit, non-government organization

CONTACT:

Maria Raquel Lucas
mrlucas@uevora.pt

NUMBER OF MEMBERS:

At the moment, there are no formal members. Nevertheless, there are several potential individual and institutional members.

CITY PROGRAMS:

- Continuum Naturale
- Urban Ecological Reserve
- National Ecological Reserve and National Agriculture Reserve
- Urban green corridor
- Urban farming

FURTHER ACTIVITIES:

- Partnership with the municipality of Évora, concerning the development of a program for urban agriculture/farming
- Diagnosis of Portuguese municipal programs related to the mission and objectives of the association
- Debate, promotion and spreading of best practices related to the mission and objectives of the association – oriented toward the educational community and society

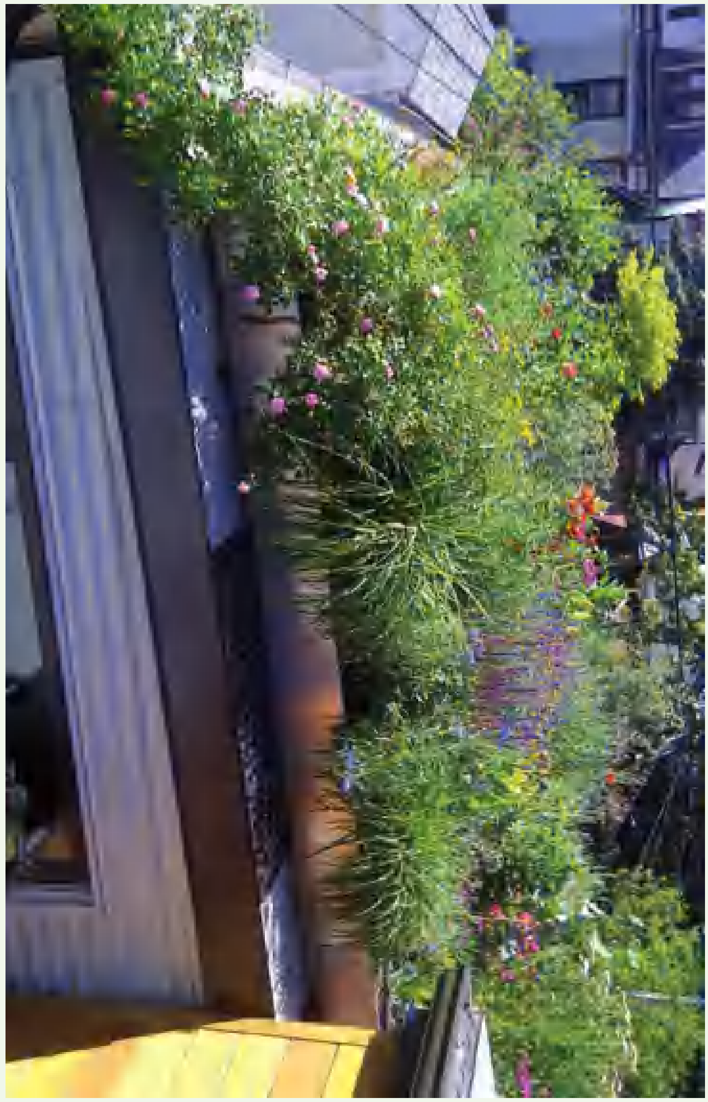
ACADEMIC RESEARCH INSTITUTIONS:

- CEAP - Centro de Estudos de Arquitectura Paisagista – “Prof. Caldeira Cabral” (Center of Landscape Architecture Studies – “Prof. Caldeira Cabral”), Agronomy Institute, Lisbon University
- CEFAGE - Centro de Estudos e Formação

Avançada em Gestão e Economia (Center for Advanced Studies in Management and Economics), University of Évora, Portugal
- CHAIA – Centro de História de Arte e Investigação Artística (Centre for Art History and Artistic Research), University of Évora, Portugal
- CICS.NOVA - Centro Interdisciplinar de Ciências Sociais (Interdisciplinary Center for Social Sciences), New University of Lisbon, Portugal
- ICAAM – Instituto de Ciências Agrárias e Ambientais Mediterrânicas, University of Évora, Portugal
- CMADE – Centre of Materials and Building Technologies of University of Beira Interior-Faculty of Engineering with collaboration of Superior School of Agronomy of Polytechnic Institute of Castelo Branco (IPCB-ESA).

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

- Cabral, F. C. (1993). Fundamentos da arquitectura paisagista. Lisboa: Instituto de Conservação da Natureza.
- Cardoso, I. (2013). Paisagem Património. CHAIA/UE: Dafne Editora.
- DGOTDU (2004). Contributos para a Identificação e Caracterização da Paisagem em Portugal Continental. DGOTDU, Lisboa.
- DGOTDU (2011). A Paisagem na revisão dos PDM-Orientações para a implementação da Convenção Europeia da Paisagem no âmbito municipal. DGOTDU, Lisboa.
- Domingues, A. (2011). Vida no Campo. Porto: Dafne Editora.
- Freire, M. & Ramos, I. (2013). Shocking ShoppingScapes. In International Conference *ShoppingScapes*, Universidade Lusófona, Lisboa. Portugal, 28-30 maio, 2013. (no prelo)
- Magalhães, M. R. (2001). A arquitectura paisagista. Morfologia e complexidade. Lisboa: Estampa.
- Magalhães, M. R., 2007. Estrutura Ecológica da Paisagem. Conceitos e Delimitação - Escalas Regional e Municipal. Centro de Estudos de Arquitectura Paisagista – "Prof. Caldeira Cabral". Instituto Superior de Agronomia – Universidade Técnica de Lisboa. ISAPress.
- Magalhães, M. R. (2010). Environmental planning and urban agriculture. The circle of life. European Union. PS Plublic Service Review (20): 598.
- Manso, M.& J. C. Gomes (2013). Desenvolvimento de um sistema modular de superfícies ajardinadas para a construção e reabilitação de edifícios, II Fórum Engenharia Civil – UTAD.



Green Roof. Source: Greenroofs.com. Photo Courtesy of Vitaroofs International Inc.

- Manso, M. (2012). Modular system design for vegetated surfaces with alkaline, International Workshop on Environment and Alternative Energy, Greenbelt, Maryland.
- Pinto, R (2007). Hortas urbanas: Espaços para o desenvolvimento sustentável de Braga Dissertação de Mestrado em Engenharia Municipal, área de especialização em Planeamento Urbanístico, Universidade do Minho.
- Ramos, I. & Freire, M. (2013). Diversidade e adversidade urbana, uma oportunidade de retorno da atividade agrícola em meio urbano. O caso estudo de Évora. IX Congresso da Geografia Portuguesa Geografia: Espaço, Natureza, Sociedade e Ciência, Évora, 28 e 30 de novembro de 2013.
- Telles, G. R. (1997). Plano verde de Lisboa. Componente do Plano Director Municipal. Lisboa: Edições Colibri.
- Telles, G. R. (2002). A perca da complexidade da paisagem portuguesa. Jornal Arquitectos, 206 (Maio/Junho), 73-78.
- Telles, G. R. (1996) Um novo conceito de cidade: a paisagem global, Contemporânea Editora, Conferências de Matosinhos – Câmara Municipal de Matosinhos, Matosinhos, Portugal, pp. 7-20.

FUTURE TRENDS:

- Strengthen the links between educational questions and nature
- Reinforcement of ethical questions related to nature and culture
- Emphasize landscape values
- Landscape urbanism
- Urban farming
- Climate change
- Collaborative consumption

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

- Professor Gonçalo Ribeiro Telles
- Professor Alexandre Cancela d'Abreu
- Professora Manuela Raposo Magalhães
- Professor Álvaro Domingues
- Professor Teresa Pinto Correia
- Professor Carlos Souto Cruz
- Professor Orlando Ribeiro
- Professor João Castro Gomes
- Professora Fernanda Delgado

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET:

Over the last few decades, Portugal has seen the development of technical, scientific and innovative efforts oriented toward improving nature integration into urban and rural areas. Annually, there is an increasing number of municipalities and non-governmental agencies and institutions involved in the research and teaching of urban agriculture. Consequently, Portugal has experienced an increase in agricultural areas in urban spaces and, simultaneously, growth of a variety of incentives (pilot projects, educational programs and trainings, etc.).

RECOMMENDED NATIONAL WEBPAGES:

- http://naturlink.sapo.pt/
- http://www.portau.org/
- http://coberturasverdes.com/
- http://www.icnf.pt
- http://www.apep.pt

AREA: POLAND

National organization:
dachyzielone.info webservice
Wołomińska 134
PL-05-250 Ciemne
phone +4822 371 09 92
fax +48 22 357 89 85
redakcja@dachyzielone.info

STRUCTURE AND MISSION:

Mission:

Publicizing of the green roof knowledge in Poland to respond the lack of professional knowledge and support delivery of green roofs to the professionals and stakeholders in the country.
dachyzielone.info webservice is aimed to serve as the source of information, news and resources about planning, execution and upkeep of green roofs as well as the platform for sharing views and experiences for people concerned with the quality of urban landscape and sustainable architecture in Poland.
The target audience is estimated at some 4 thousand users (including about 1.8 thousand registered users).
The service offers access to the professional green roof e-magazine Dachy Zielone (Green Roofs) available online free of charge in both flash and pdf formats. The magazine is designed to help transfer the knowledge and knowhow of green roofs in Poland as well as to add to environmental education and build-up of the environmental awareness.
The e-magazine was launched in January 2010 and three issues were released since then. Selected materials are available with abstracts in English and Russian and reprinted by the leading professional magazines, such as Zieleń Miejska (Urban Greenery), Murator and Dachy Płaskie (Flat Roofs).

Structure:

Private non-profit initiative

CONTACT:

Ewa Piątek-Kożuchowska.
Editor. Mobile +48 503 127 874
ewa.piatek-kozuchowska@dachyzielone.info

HOMEPAGE:

www.dachyzielone.info/

NUMBER OF MEMBERS:

About 1.8 thousand registered users

FURTHER ACTIVITIES:

"CHANGE GREY INTO GREEN"
Green roofs & living walls in Germany - examples of best practices. Study visits in Germany for Polish university teachers, secondary school teachers & green roof trainers. This project funded with support from the European Commission under the Lifelong Learning Program on the initiative of dachyzielone.info together with the Green Roof Centre of Excellence at the University of Neubrandenburg.
The aim of the project is to transfer best practices and exchange of experience in the field of green roofs and living walls between the

partners from Germany and Poland. The participants of the project will be university teachers, vocational school teachers and trainers involved in this issue in Poland. The participants will be recruited from the candidates working in public and private universities for faculties of landscape architecture and environment protection, in vocational schools profiled in landscape architecture and gardening and in other forms of vocational training for the adults.

The project will include two exchange experiences, each for a group of 20 people, in spring and autumn 2014 (7-12 April and 29 September - 5 October). The hosting partner will be the Green Roof Center of Excellence at the Department of Landscape Architecture at the University of Applied Sciences in Neubrandenburg. A visit to Berlin will be organized in cooperation with the City of Berlin. The project will be completed in March 2015. Details in Polish and English are available on the project website:
www.zamienszarenazielone.pl

Steep Extensive Sedum roof construction. Source: M. Köhler.

AREA: SCANDINAVIA

National organization:
Scandinavia Green Roof Association (SGRA)
Tel: 040948520
E-Mail: peter.lindhqvist@malmo.se

STRUCTURE AND MISSION:

Scandinavian Green Roof Association (SGRA) is a not for profit organization. Among the members of Scandinavian Green Roof Association a majority of Malmö's departments and a majority of all green roofs installers in Scandinavia is represented, among a couple of other organizations from various fields such as the university of Malmö, architect firm and waterproof installers. The board of SGRA consist of persons from all different fields and goal is to have a board which represent all sides of the green roof market; installers, contractors, designers, academia and green roof customers. Since the end of the 1990s SGRAs mission has been both to increase the green roof and façade greening market and to raise the quality of products and maintenance.
In 2001 SGRI formed the Scandinavian Green Roof Institute (SGRI) to manage the development of Augustenborg Botanical Roof Garden – the first and one of the biggest public botanical roof garden in the world with its 9500 square meters. In the beginning of 2000 SGRI developed advanced research & demonstration activity to promote Green Roof development in Scandinavia which 2006 resulted in the first doctorate of green roofs in Scandinavia and an ongoing close partnership with the Swedish University of Agricultural Science (SLU).

CONTACT:

Jonatan Malmberg (President) (Superintendent at Augustenborg Botanical Roof Garden and SGRI)
jonatan.malmberg@greenroof.se

HOMEPAGE:

www.greenroofs.se
http://greenroofmalmo.wordpress.com

NUMBER OF MEMBERS:

About: 20 members

FURTHER ACTIVITIES:

In 2012-2013 SGRI began to develop vocational green roof training material and initiated collaboration with upper secondary and vocational Schools in the Öresund region.
The work with producing course material continued in the autumn and winter of 2013, with the creation of online green roof course material - both as a complement to the vocational courses and as an e-course platform for university green roof e-course.

Sod covered roofs on a farm house in Vislanda, Sweden. Source: Greenroofs.com. Photo Courtesy of Linda S. Velazquez.

ACADEMIC RESEARCH INSTITUTIONS:

Swedish Agricultural University (SLU) is represented in SGRAs board.

CURRENT TRENDS:

Interest for green roofs is increasing but the interest of living or green walls is growing even more. And even though a great interest there is no city in Sweden that can compare itself with the current development in Copenhagen.

NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

In Sweden:
Tobias Emilson (SLU Alnarp)
Ann-Marie Fransson (SLU Alnarp)
Sofia Eskilsdotter (SLU Ultuna)
Lars Johansson (SLU Ultuna)
Cleas Florgård (SLU Ultuna)
Jonatan Malmberg (SGRI)
Annika Kruuse (Malmö City Environmental Department, project manager of the BiodiverCity project)
Kristina Mårtensson (SWECO Stockholm office)
Per Nyström (CEO Nyfam. Started Vegtech in early 1990s)
Jan Wijkmark (White Architects, Stockholm)
Torgny Henriksson (Byggros Sweden)
Mattias ... (Urbio Architects)
Milan Obradovic (Social Democrates – Malmö City.

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET

Observed trend green roofs:

Green roofs is becoming more and more popular in Sweden and mostly extensive green roofs. However, demand and interest of intensive green roofs is raising, and one reason is that the City of Stockholm is planning to increase their green space on garages and houses dramatically in the future to meet the demand of both new developments and green space.

Observed trend green walls:

There exists at least 7 serious out door green wall experiments in Sweden. In Stockholm, Malmö and Gothenburg – initiated both by academia (SLU and State) and companies (White Architects, PEAB, Concrete Farming, Odlingsnätverket and NCC). However, despite the growing interest the amount of green walls installed for other purposes that research is very, very few.
The indoor greening market, we are not informed about trends in this field.

RECOMMENDED NATIONAL WEBPAGES:

www.greenroof.se

AREA: SINGAPORE

National organization:
There is no professional nor academic organisation in Singapore that focuses on green roofs and/or vertical greenery (which is collectively termed as „skyrise greenery.“)
The closest and most relevant organisation in that aspect is the government agency, Centre for Urban Greenery and Ecology (CUGE, in short), which is under the National Parks Board (NParks, in short).

STRUCTURE AND MISSION:

CUGE is jointly established by the NParks and the Singapore Workforce Development Agency. CUGE has a critical mass of knowledge to share and advance expertise on urban greenery and ecology, including skyrise greenery.
NParks is responsible for providing and enhancing the greenery, including skyrise greenery, of Singapore. It also manages parks, nature reserves, streetscapes or roadside greenery.
Verditecture Private Limited is a Singapore-registered private company that focuses on skyrise greenery and also WGIN's representative in the South East Asian region.

CONTACT:

- skyrisegreenery@nparks.gov.sg
- admin@verditecture.com

HOMEPAGE:

- *www.nparks.gov.sg*
- *www.skyrisegreenery.com*
- *www.verditecture.com*

CITY PROGRAMS:

- Skyrise greenery incentive scheme ("SGIS" in short)
- Skyrise greenery sharing sessions and talks
- Skyrise greenery awards

CONFERENCES:

International Skyrise Greenery Conference

MEMBERSHIP:

n.a.

ACADEMIC RESEARCH INSTITUTIONS:

- NParks CUGE
- Housing and Development Building Research Institute (HDB BRI)
- National University of Singapore (NUS)
- Nanyang Technological University (NTU)

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

There are too many. Papers from Dr Tan Puay Yok, Prof Wong Nyuk Hien and Ms Angelia Sia.

CURRENT TRENDS:

Interest for green roofs is increasing but the interest of living or green walls is growing even more.

GROWTH RATE RELATION BETWEEN EXTENSIVE / ROOF GARDENS/ PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET

4 – 6% per year

RECOMMENDED NATIONAL WEBPAGES:

www.skyrisegreenery.com

AREA: SPAIN

National organization:
PRONATUR.
Department Agricultural Economics and Social Sciences. ETSI Agronomos. 28040 Madrid

BACKGROUND:

The historical evolution of green areas in Spain may be summarized as.

Traditional period
It includes all the spontaneous green roofs actions taken by institutions or individual persons. As Mediterranean country, the soil and weather conditions have restricted the type of vegetation. However, there have been examples of intensive green areas, even with exotic plants.

Green Renaissance period
In Spain, following models of other countries (Germany, the Netherlands, USA), in the 90's decade, it started a movement with "ecological mentality". Professors, researchers, civil servants, entrepreneurs and citizens in general, consider the necessity to collaborate in the introduction of green areas inside the cities, called "naturación urbana" (urban greening).
In 1989 it was founded the non-profit organization PRONATUR (Promoción de la Naturación Urbana y Rural). It was a period, new experimental green roofs, research programs, national and international seminars, Ph.D. Thesis and publication . The society reacted with interest in mass media (TV, newspapers). The Spanish Nobel Prize winner, Camilo José Cela, wrote an article about the "idealistic people of the green roofs".

Consolidation period
After the renaissance, the experience shows the need for some analysis. In first place, it is necessary to consolidate the goals reached in the last years and, secondly, there is a need to expand the activity according to the society needs.
The challenging is how to continue with the coordination between Research – Regulation and Reconstruction.
The Research Group ABIO (Bioclimatic Architecture, Sustainable Environment) has been a very dynamic group of joint venture of University and enterprises. In Zaragoza, there is another group (Sicilia Arquitectos) working in greening areas with participation in International Fairs and local institution.

STRUCTURE AND MISSION:

a) PRONATUR (Spanish Society for the Promotion of Nature in Urban and Rural Areas) is a non-profit and non-governmental organization. It was founded in April 1996 with the collaboration of IASP (associated to Humboldt University of Berlin).
b) Board of directors as of 2013:
- President and founder: Emeritus Professor. Julián Briz. U.P.Madrid.
- Vice President: D. Joaquín Sicilia. Firm Sicilia Architect.
- Secretary: Nuria Lacaci. Firm Asoteimp.
- Treasurer: Prof. Beatriz Urbano. U.Valladolid.
- Directors:
  - Prof. Isabel de Felipe. U.P.Madrid.
  - Prof. Jose Mª Duran. U.P.Madrid.

Previous Board of Directors:

- President and Founder: Professor Julián Briz. U.P.Madrid.

The World Expo Zaragoza. Spain. Source: Greenroofs.com. Photo Courtesy: ZinCo.

- Vice President: D.Jesus Perez. Firm Danosa.
- Secretary: Nuria Lacaci. ANFI. National Association of Firms.
- Treasurer: Prof. Isabel Rico. U.P.Madrid.
- Directors:
  • Francisco Ruiz. Firm: Intemper.
  • Prof. Cesar Gomez Campo. U.P.Madrid.
  • Prof. Francisca Guerrero. U.P.Madrid.
  • Prof. Mª del Carmen Cartagena. UP Madrid

c) The goal of PRONATUR is to promote and coordinate activities of science, research, technology and firms for improvement of nature in urban and rural environments.
Some of the guidelines for PRONATUR are focused on:
- Greening buildings
- Green streets and open spaces in the city
- Action in urban agriculture
- Research and development, looking for synergies between academics, entrepreneurs and practitioners

d) As a way to promote urban agriculture in 2012, the Observatory of Urban Agriculture was founded in coordination with Foro Agrario.

CONTACT:

PRONATUR office: Julian Briz
julian.briz@upm.es
julian.briz@hotmail.com

HOMEPAGE:

www.pronatur.es / *www.pronatur.chil.org*

NUMBER OF MEMBERS:

Including the Observatory of Urban Agriculture, about 200. There are academics, technicians, entrepreneurs, practitioners and neighborhood organizations.

CITY PROGRAMS:

The more important cities in Spain (Madrid, Barcelona, Sevilla, Zaragoza, Valencia) have developed local programs to improve green infrastructures. Special attention has to be given to Vitoria, nominated European Green City in 2012. There are not aggregate official statistics of greening programs results. However, in many Spanish cities there is a growing trend in green buildings. As example, in Madrid, some of the more significant projects are the Barajas Airport, Santander Financial City, Caixa Forum, hospitals, rooftop farms, and others.

CONFERENCES:

a) Agreements and membership:

- 1999: Red Internacional de Ciudades en Naturación (RICEN) – in coordination with IASP (Humboldt University Berlin)
- 2002: Member of the European Council for the Village and Small Towns (ECOVAST)
- Since 2010: Member of WGIN
- As of 2013: A cooperation agreement with “La Comunidad Verde”, a Spanish professional association of 13 companies involved with green cities and urban agriculture.

b) National and international seminars and congresses:

- 1999: International seminar in Madrid about “Bioclimatic Architecture and Urban Nature”
- Participation with IASP in the International Congress on Urban Greening and Agriculture in: Quito (Ecuador), Cartagena de Indias (Columbia), Cuba (Havana). Rio Janeiro (Brazil)
- Participation in the WGIN International Congress in: Canada (Toronto), Mexico DF, India (Indore), China (Hangzhou), France (Nantes)
- 2010: Contribution and discussion in the Urban and Peri-urban Agriculture and Urban Planning (FAO-ETC) (www.fao.org/urbanarg/240800)
- Collaboration in international master courses about green cities sponsored by the EU at Chapingo University (Mexico).
- Postgraduate courses in bioclimatic architecture at the Faculty of Architecture in UPM.
- Virtual courses in “naturación urbana” (greening cities) at Valladolid University
- Project in urban agriculture in collaboration with foreign countries (Mexico, Peru, Bolivia, Argentina, Cuba).
- Project about impact of environment in the green roof performance. Program INNOVA-CORFO with Chile.

ACADEMIC AND RESEARCH ACTIVITIES:

- In 1994, from the City Hall of Madrid, PRONATUR received recognition in the field of “Urban Environment”.
- In 1993, in collaboration with the City Halls of Berlin and Madrid, an experimental green roof was built at the Department of Agricultural Economies in the Escuela Técnica Superior Ingenieros Agronomos (ETSIA) Ciudad Universitaria, Madrid.
- In 1996, through a research project of the Polytechnic University of Madrid (UPM), a second experimental green roof was created at the Department of Phytotecnic (ETSIA).
- In 1997, the first experimental green roof was remodeled with new electronic devices.
- In 1999, a research project was sponsored by the ministry of Industry and Energy, and, as collaboration between Intemper and UPM, an experimental green roof was built in Colmenar Viejo (Madrid), focused on the research of the energy saving potential of green roofs.
- 2013. Research project on green walls (UPM and private companies).
- Projects: Sponsored by several universities (UPM, Humboldt) City Halls (Madrid, Berlin), and regional governments
- 4 PhD Theses
- 3 Master’s Theses
- 12 Academic Final Projects of agricultural engineers

- Member of the team coordinated by the Technical Agricultural School of Barcelona publishing the handbook of "Standard construction on green roofs".

MEMBERSHIP:

Member of WGIN

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

a) Books:
- Naturación Urbana: "Cubiertas ecológicas y mejora medioambiental" Mundiprensa. Madrid. First Edition: 1999. Second Edition: 2004
- The hidden garden: Green spaces in the city. P. Sampietro. Pollen. 2014.

b) Articles and communication to congress.

CURRENT TRENDS:

- Mediterranean roof and wall gardens
- Urban agriculture
- Carbon and energy footprint evaluation and under the focus of green urban areas.
- Adaptation of green roofs to special conditions: dry and windy weather, green buses in the cities.
- Roof top farming.
- Improve the coordination of synergies between actors (public and private sector) involved in greening cities activities.

RECOMMENDED NATIONAL WEBPAGES:

- www.pronatur.es
- www.lacomunidadverde.com
- www.phytokinetic.net
- www.asecuve.net

Delicias Plaza. Zaragoza. Spain. Source: Joaquín Sicilia.

AREA: TAIWAN

National organization:
Taiwan Green Roof & Green Wall Association
Office Address: 6-3, 160, Section 6, Mingchuen East Road, Neihu, Taipei, Taiwan
Phone: 886-2-27923958
Fax: 886-2-87919495

STRUCTURE AND MISSION:

The Taiwan Green Roof & Green Wall Association was formed on May 18th, 2011, by a group of environmentally-conscious people consisting of professors, architects, developers, landscape designers and contractors, and horticulture supply companies. It is officially incorporated as a nation-wide non-profit institution.
The missions are to:
- Develop and provide products and technologies for the green roof and green wall industry
- Establish and publish industry standards and practices
- Promote and educate the public on benefits and safety concerns
- Assist governmental agencies in devising policies and measures to impose compulsory green roofs and green walls
- Train and certify qualified installers
- Secure legislative and financial support from government at the central and city/county levels of government
- Network with relevant associations in promoting green building concepts and practices.

CONTACT:

Nelson Li, President

HOMEPAGE:

http://www.greenroof.org.tw

NUMBER OF MEMBERS:

- Individual members: 60
- Corporate members: 21

CITY PROGRAMS:

New Taipei City green roof project, Taipei City Green roof guidelines, Kaohsiung City greening guidelines, Taichung greening guidelines

CONFERENCES:

Local counties or cities have sponsored green roof seminars each year with the help from the Taiwan Greenroof Association. No national or international conferences have been held yet.

FURTHER ACTIVITIES:

Green roof conferences in the 6 major cities of Taiwan are planned for 2014

MEMBERSHIP:

Member of WGIN

ACADEMIC RESEARCH INSTITUTIONS:

- National Taiwan University
Department of Horticulture and Landscape Architecture
http://www.hort.ntu.edu.tw/main.php

- Chinese Culture University
Department of Landscape Architecture
http://www2.pccu.edu.tw/crtdla/english.htm

SELECTED NATIONAL SCIENTIFIC PUBLICATION:

Parks & Greenland Association publications, "I love Grenroof" published by "Myhouse"

CURRENT TRENDS:

High rise greenery is becoming more and more popular as some skyscraper-style apartments have been introduced. Roof gardens are becoming popular. Storm water management is another key concern here which helps the installation of green roofs

SOME NATIONAL KEY PERSONS OF GREEN INFRASTRUCTURE:

- Hsien-Der Lin, Green Building Council
- Nelson Li, President of the Taiwan Greenroof Association
- John Li, Chairman of Taiwan CECI
- Monica Kuo, Department head of Landscape Design at Culture University
- Y. S. Chang, Professor at National Taiwan University
- C. M Kuo, Curator of Botanical Sample library of National Taiwan University

GROWTH RATE RELATION BETWEEN EXTENSIVE /ROOF GARDENS/PODIUM DECKS AND SOME WORDS ABOUT LIVING WALLS AND INDOOR GREENING MARKET

The growth of the green roof and green wall industry is at about 20-30% a year due to the fact that local governments are pushing for compulsive green roofs in new construction projects. However, intensive green roofs are usually preferred. For existing buildings, on the other hand, extensive green roofs are more popular because of dead-load constraints.
Green walls are very popular as the local governments require compulsory green walls on the fences of construction sites. More and more permanent types of green walls have been installed as well as the indoor green walls in restaurants and shopping arcades. The current constraint is the technology to keep them sustainable. Maintenance costs are rather high and some architects criticize that green walls consume too much water and energy.

Roof garden as Art installation. Source: M. Köhler.

RECOMMENDED NATIONAL WEBPAGES:

http://www.greenroof.org.tw

Attended by hundreds of thousands of visitors each year, ArtPrize 2013 included a living entry, the "Back to Eden" greenwall, which unites the bonds between art, architecture and nature. Source: Greenroofs.com. Photo Courtesy of LiveWall.

We are in a period of increasing migration from rural to urban areas, and cities will soon contain 80 per cent of the human population. Simultaneously, nature is in demand by citizens and innovation in building construction allows us to integrate green areas into our environment.

The book *Green Cities in the World* is the result of a convergence of interest from individual, public and private institutions looking providing the urban society with a reference publication which from a diversity of the main topics and opinions in the green urban market.

The mix of academics, practitioners, entrepreneurs and professionals in this publication leads to fruitful interactions and provides new insights into the green urban developments of the world.

The publication has 16 chapters, with 23 authors and reports from 25 national areas in 360 pages.

The structure is organized in four scenarios: Economy, Sociology and Policy; Environment; Architecture and Technical, and National Stories.

PRONATUR

WORLD GREEN INFRASTRUCTURE NETWORK
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