MULTIFUNCTIONAL URBAN GREEN INFRASTRUCTURE

Editors: **Julián Briz, Manfred Köhler, Isabel de Felipe**

Food Health Biodiversity Environment

Recreation Biomimetisme SDG Socioeconomics

Energy Landscape Climate change

MULTIFUNCTIONAL URBAN GREEN INFRASTRUCTURE

Editors: **Julián Briz, Manfred Köhler, Isabel de Felipe**

Food
Health
Biodiversity
Environment
Recreation
Biomimetisme
SDG
Socioeconomics
Energy
Landscape
Climate change

WORLD GREEN INFRASTRUCTURE NETWORK
vegetation makes it possible!

PRONATUR

Title:
Multifunctional Urban Green Infrastructure

Edition:
© Julián Briz, Manfred Köhler, Isabel de Felipe

Design:
Editorial Agrícola Española S.A.
Daniel Fernández-Caro Chico
Editorial Agrícola Española S.A.

ISBN: 978-84-92928-96-5
ISBN (Digital): 978-84-17884-00-0
Depósito Legal: M-11856-2019

INDEX

Green roof in Spain.
I. de Felipe

PREFACE

The World Green Infrastructure Network continues with its own publications. After its first book "Green Cities in the World" in 2014, the update in 2015 and the Spanish version in 2016, the "Vertical urban agriculture" book followed in 2018. Now you have our new book in your hands, which also updates the overview of national green infrastructure associations around the globe.

The present book is a product of several WGIN members and other selected authors. We are very grateful to all these contributors. The aim of this new book is to highlight some specific examples of implemented projects around the exiting world of green infrastructure. One focus are insight stories about lessons learned in green infrastructure.

Why this collection?

Green infrastructure has become a hot topic all around the globe; this book can help to expand your knowledge about the associated benefits. Combining construction with plants and incorporating their functionality into the architectural design is today much more accepted than years ago.

This publication is an insight view of several pioneer projects and some detailed solutions, which are worth replicating or adapting to other climates, regions or cultures.

Many thanks to the authors who delivered their stories, as well as to the corporate members of WGIN, who supported this project. Every implementation of green infrastructure projects needs competent partners, have a look at what they have to offer.

We are on a tour with more stories coming up, so pay attention to the next WGIN-congresses with face to face contacts. Meanwhile here are some stories – we are happy about responses and we would like to get to know your thoughts about green infrastructure in some feed-back to the authors and editors.

I also want to thank Isabel de Felipe and Julian Briz for all their great editing work and their belief in the printed word, though we are also going digital – this book is available as e-book or pdf in order to reach as many readers as possible.

Green infrastructure offers some answers to several of today's big questions and urban problems like urban heat island mitigation, rain water management and biodiversity, and last but not least, Green roofs and all other green structures are very enjoyable if they are well done.

For much more greenery in future cities – there is the space and the need.

Enjoy the reading.

Manfred Köhler
WGIN President
February 2019

Wintergarden.
MÅhlgrund. Vienna.
Auboeck-Karasz

FOREWORD

The publication of the book Multifunctional Urban Green Infrastructure calls the attention on the variety and heterogeneous effects of green areas in our daily life.

Urban Green Infrastructure has both a direct and indirect functions. Some of them are visible in the short run: energy saving, water management, recreation, food supply and healthy environment among others. In our former publications ("Green Cities in the World" and "Vertical Urban Agriculture"), there is a description of technical and socioeconomic dimensions related to those functions.

The present publication describes some functions with an indirect effect in the long run. While direct function are easy to identify, evaluate and measure, it is more difficult to do it with the indirect ones. Frequently, these indirect functions are hidden or forgotten by our society (biomimicry, botanic research). Therefore, there are some barriers to expose clear arguments to the citizenship and get resources for their activities.

Consequently it is very important to explain to public opinion the relevant role of green urban infrastructure in our daily life. Politician, technicians and functionaries should have clear ideas about all their dimensions in order to improve urban life.

The 17 chapters include some of the mentioned multidimensions. This publication is organized in three different sections. The first one about functions, the second one about experiences in some countries and the third one deals with national organization related to green urban infrastructure.

One of our goals has been to emphasize the importance of green urban infrastructures for a sustainable horizon of our cities, with a description of practical examples in some countries. Finally, there are some guide lines for the reader, about national and international organizations of green urban infrastructures, to stimulate getting in touch with colleagues, professionals and academics.

Madrid, February 2019
Julián Briz, Isabel de Felipe

Globaler Hof. Vienna.
Auboeck-Karasz

ACKNOWLEDGEMENT

Multifunctional Urban Green Infrastructure have a broad and holistic scenario which includes a great variety of topics and the concourse of different professions.

In this publication, we have had the opportunity to get the collaboration of authors who develop very different activities in several countries. WGIN and PRONATUR have been the melting pot where the basic ideas has been selected and discussed for several years.

We profit also of the relationship with the Hochschule Neubrandenburg (Germany) and itdUPM (Spain) which have provided human and socioeconomic resources in favor of the green infrastructure.

Special acknowledgments to the sponsors Carl Stahl, Kanauf Insulation, Sempergreen and Taktorv which cooperate to finance the publication and give to us the opportunity to divulge and extend the knowledge about urban green infrastructure .

We thank to the authors who have dedicated their knowledge and enthusiasm in this task.

Last but not least we recognize once more the task of the publisher Editorial Agricola for publishing this book with high quality at the right time.

February 2019
Julián Briz, Manfred Köhler, Isabel de Felipe

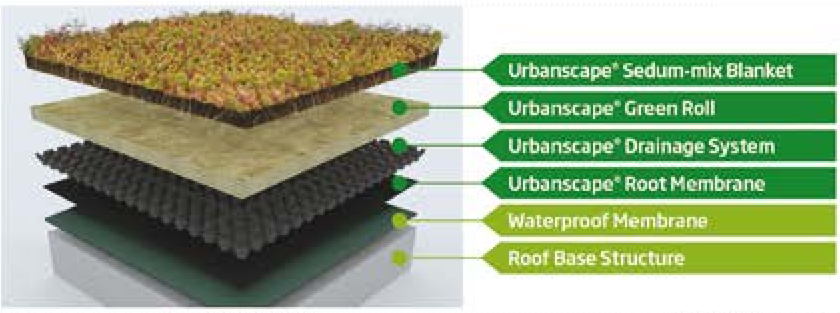
SPONSORS


Carl Stahl®
ARCHITEKTUR
I-SYS®
STAINLESS STEEL WIRE ROPE SYSTEMS
CREATIVE GREEN SOLUTIONS
EYE-CATCHING DESIGNS
100 % RECYCLABLE
LIGHT & DURABLE STRUCTURES
FOR MORE THAN 25 YEARS OF EXPERIENCE WITH WIRE ROPE AND MESH SOLUTIONS
MADE IN EU | CARBON NEUTRAL COMPANY | TESTED QUALITY
WWW.CARLSTAHL-ARCHITEKTUR.COM
Carl Stahl ARC GmbH | D-73079 Süßen | architektur@carlstahl.com | Tel: +49 7162 / 948150-100

TAKTORV®
GreyToGreenCity
Over thirty years of experience.
Documented effect.
NITTEDAL
TORVINDUSTRI A.S
www.nittedal-torvindustri.no

Urbanscape®
Green Roof System

A complete, lightweight and easy to install system with high water retention capacity.



Green roofs: designed to reduce urban heat island effect and manage stormwater effectively and efficiently!

Benefits

- Complete solution
- Lightness
- High water absorption
- Efficient installation
- Sustainability

KNAUF INSULATION

www.urbanscape-architecture.com

urbanscape®

Knauf Insulation d.o.o.
Trata 32, 4220 Škofja Loka, Slovenia
Tel: +386 (0)4 5114 000 E-mail: urbanscape@knaufinsulation.com

Above and beyond

Berlin. Kerstin Rîrich

PART 1
FUNCTIONAL ACTIVITIES

Green Wall.
Santo Domingo Hotel.
Madrid. I de Felipe

CHAPTER 1

SMART URBAN ENVIRONMENT: A CHALLENGE IN A CLIMATE CHANGE FOR GREEN INFRASTRUCTURES

Julián Briz
President of PRONATUR

Isabel de Felipe
itdUPM

INTRODUCTION

Urban climate change improvement is a very broad and complex topic; consequently, it requires a holistic approach. All the stakeholder involved need to be coordinated with different interaction. Private and public sector have to design a multiscale agenda, where environmental urban policy match with the available technologies and human resources. Thus, urban society may have the resilience capacity to face new challenges.

Urban green infrastructure contributes to mitigation of climate change in different scenarios. At a global horizon, their influence is in the long run with lower significance. However, in city limits, the results are short term and more relevant, so the dweller may check them. Green roofs and walls have became more important in the second position, due to the lack of available land in the city. For instance, the idea of the green corridor in roofs and walls may facilitate the cooling of areas and wind movement, which clean the polluted air.

Green infrastructures play a significant role in our urban environment, through multifunctional activities. We focus on the attention in climate change and the positive impact of green areas.

Concerning urban environment, some questions have rising recently (EU, 2018), related to Smart cities, including climate change due to their direct and indirect impact in our daily life. Climate Smart Change (CSC) is an important element for Smart Urban Environment (SUE) evolution. In addition, SUE is a component of Ecology Cities, which is a requirement for Smart cities. In this way, there is an interaction between CSC and SUE.

At the special seminar "Who owns the right to the city? EU Research and innovation for inclusive urban regeneration" organized in Brussels on October 9th, 2018, some significant questions were raised: How can the city contribute to urban inclusivity? What challenges have to move towards inclusive urban regeneration? How may the Research and Innovation actions reduce gentrification and inequalities within and between cities? Partial solutions to these questions may be solved by the Green Infrastructures actions, which move urban areas toward the Ecocities scenario. However, the urban environment is very complex and with great diversity, therefore we describe different items in a brain storming way in order to call the attention of some of the most significant scenarios.

Another important element for the analysis of city environment is the concept of natural capital in the urban Green Infrastructure (GI) which provides socioeconomic benefits to citizens for free, such as recreation spaces, healthier air and environment. In economic words, we may identify the GI as positive externalities. (Greater London Authority. October 2017) Natural capital has to be allocated establishing priorities according urban demographic distribution, air and acoustic pollution and social demands.

Although in general GI create positive effects in the city, most of them are focused on the local resident of certain areas. GI urban policies are costly for the community; therefore, the promoters have to demonstrate clearly the net value of recreation, amenity, property prices and other positive externalities.

Traditional GI are identified in parks and tree streets, but there is a geographic limitation to expand them in most cities. Therefore it is necessary to strengthen vertical urban farming, occupying underused spaces (walls, roofs), as important issues.

But GI also include agricultural urban farming (Lipper et al. 2014).In this orientation we need an approach for transforming and reorienting agricultural systems to support food security under climate change. Coordinating actions by farmers, policymakers, public and private institutions, research and university organizations, will increase efficiency and innovation. The three pillars of Climate Change nature based are productivity (sustainable intensification), adaptation (protect ecosystem services) and mitigation (reduce greenhouse gas emission).They are the challenges of large cities for improving their economic competitiveness in a sustainable environment and maintaining investment and skilled workers (ISPI. 2008)

There is a societal acceptance for urban agriculture (UA) in the traditional way but some negative reactions for artificial high tech. UA offers new models for the coming future with opportunities for gender balance, community interaction and social inclusion of refugees (EP. 2018 page 29).

UA provides public goods to urban dwellers, mainly related to socioeconomic and environmental dimensions. The reduction of carbon and energy footprints, circular economy, food quality, biodiversity and climate change reductions. Green Infrastructures offer a great variety of forms, from backyard gardens o community garden roofs and Green walls, urban farms and others. However, UA has been neglected by local and national policies. Recently academic and policy makers consider a lack of action in programs for research, innovation and subsidies and need to change the current situation.

Proximity to urban community gives special situation to UA, with opportunities to improve environment and life conditions. Also UA plays a bridging role between the city and rural world, with asymmetric situation in economic and political power which is in a concentration process in urban communities.

UA has a community involvement through education, cultural activities and social integration movements, a place to meet people. Besides, there are intercultural gardens where heterogeneous population such as refugees and immigrants may interact, based in respect and tolerance, with communication during farming activities, maintaining their cultural diversity. (Moulin- Doos, C. 2014).

Structure and socioeconomic transformations in UA will happen in the coming future: From old to young persons, from amateurs to professional farmers, UA will be a new proactive business model with innovation in green infrastructures and digital technologies, farming practices and control of environment conditions in greenhouses.

Another significant element in the urban food chain value is the socioeconomic transformation of consumers, with preference for fresh vegetables, cultivated in the proximity, do-it- yourself culture, food sovereignty and so on. All of this may change also consumer habits and attitudes as citizens in relation to environmental policy programs and circular economy.

Greenhouse gas accumulation due to human activities contribute to global and local warming with catastrophic consequences in health and quality environments. Therefore, the solution comes for decreasing the emission of contaminants (traffic, central heating and others) and the inmission of them (Edwin R. et al 2007).

Green infrastructure strengths the resilience of urban environments to respond to current and future challenges to climate change and other elements (food security, biodiversity, health). A review of peer- published research between 2012- 2014 concludes as results that some of the benefits of green infrastructures are improving human health, biodiversity and climate conditions. Other positive aspects are urban food production and economic prosperity (Pitman S., et al 2015).

Urban planners need evidence to develop strategies for climate mitigation. However, there is a lack of long-term studies of urban climates and their impacts. It is important to look for cross-disciplinary projects between regions as most of the research is focused on local and single disciplines. To understand urban climate

Figure 1. Climate urban scenario

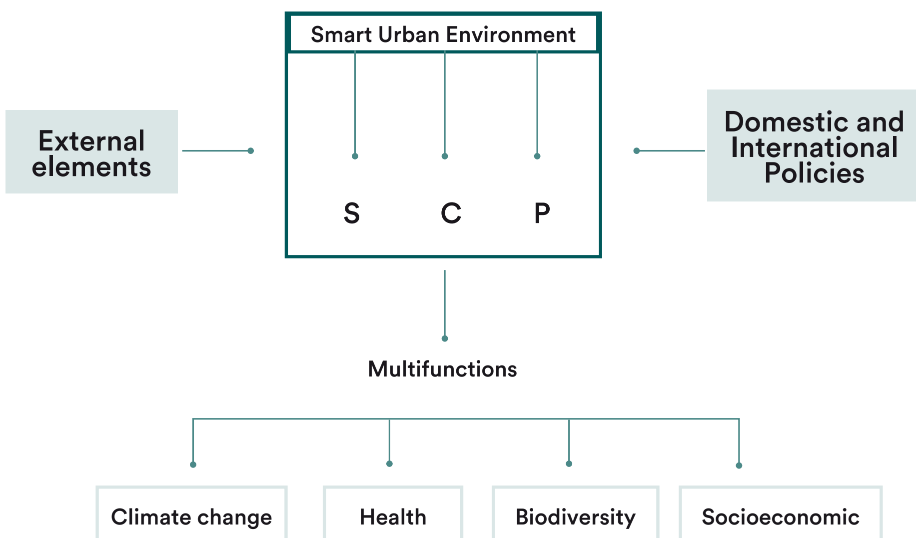


Table 1. GUI Activity and Multifuntionality Evaluation

GUI Activity	Function Evaluation							
	Landscape ornamental	Air Quality	Acustic	Food Supply	Temperature	Humidity	Recreation	Air circulation
Green wall	1	2	3		5	4	1	6
Green roof					2	2	3	4
Inside green	1	2	3					
Inside orchard				5			2	
Tree streets			3			2		1
Parks	2	2			3	4	1	3
Green towers		1			2	3		3

change we have to work in several areas: expand observations in quantity, quality and type of data collected (Bai X et al. 2018).

Climate interactions is a complex process as pollution or impermeable surfaces interact with temperature and rainfall flood. In socioeconomic horizon studying informal settlement, by 2050 three billion people will be living in slums under bad conditions affected by climate changes. Therefore, harness disruptive technologies (digital revolution, green infrastructure reducing flood risk) will support such transformation where strategies are needed for resilient cities with local innovation.

In the coming future, city stakeholders should incentive University programs and long term research, coordinated with policymakers, businesspersons and social institutions for a sustainable horizon.

Green urban infrastructure projects may be evaluated before the acceptance by the society. In the private sector, the market is the main indicator, and enterprises try to follow the customer preference. In public sector, like city halls they should try to get the opinion of urban society through direct consultants to citizens, NGOs and neighbor associations. Thus, Madrid City Hall recently inquired directly to citizens their priority for a number of project proposals where to spend a certain amount of Euros.

As a practical example, we describe two hypothetical tables about the interaction of Green Urban Infrastructure activities and their functions. (Table 1).

In Table 2) it is described the evaluation of specific projects in Madrid with the different functions. In both tables, the potential evaluation establishes the 1st , 2nd, 3rd priorities, given by the interviewed persons.

METHODOLOGY

Climate Smart is focused maintly in greenhouse gas emission, cost and carbon emission, resilient economy and business. However, in a holistic framework of new urban metropolis and looking the increasing role of Green Infrastructure (GI), it is considered relevant to analyze a "Smart Urban Environment" (SUE) in a dynamic way. Following the Industrial Organization (Belleflamme P., Peith M. 2015) theory, we may identify three steps in the Smart Urban Environment: Structure, Conduct and Performance. Structure (S) has physical dimensions,such as temperature, humidity, wind, radiations, air and pollution. The Conduct (C) relate to behavior dimensions. We may include recreation, landscape, person attitude toward GI, socioeconomic activities, cultural relations, formation. The Performance (P) is the effect in the urban society such as health, cost, investment, economic benefit and market value. While Structure and Performance may have quantitative analysis and applications,

Table 2. GUI Projects and Functions

GUI Projects	GUI Multifuntionality Evaluation							
	Landscape ornamental	Air Quality	Acustic	Food Supply	Temperature	Humidity	Recreation	Air circulation
Caixa Forum	1	1	2		2	3	1	4
Hotel Santo Domingo	2	1	1		4	5	5	2
Hotel Wellington	1	1	1	3	1	1	2	1
CF Santander	4	2			2	1	3	
Barajas Airport	1	1	3				3	
LABAU	5	1	2		3	4		1

Conduct refer mainly to qualitative analysis. There is a dynamic sequence in S -C -P in the SUE evolution.

Structure

Green infrastructure (GI) includes the green (plants) and the blue (water) places, which provides healthy and friendly environment to urban population. There is a great range of scales, from ground (parks, street trees, recreation areas) to vertical (roofs, walls). Green infrastructures(GI) have multiple functions, such as climate change, health, biodiversity and socioeconomic dimensions among others

On the other hand, Urban society do not recognize the whole role and value of GI, looking to market value of the activities, whether to have a luxury building and residences or massive housing with concrete and crystal. Therefore, we have to show the real value of GI, even the business opportunities, where entrepreneurs may get involved and obtain net profit.

On the other hand, the world is in a dynamic process of changes in climate, economy, rural urban migration, and urbanization, sociopolitical and economic scenarios. The question is not if it is going to happen, but when, where and how will do it. Another interesting point is who are the protagonists that will obtain benefits supplied by GI:

- Institutional: local administration, city hall, with actions that may increase green areas sustainability and lower cost in health programs,), reduce climate impact and damages with more efficient performance in other services (water drainage, air quality.

- Social organizations: NGOs, neighbors association. Facilitate social integration, cultural activities, creation of orchard and gardening activities.

- Entrepreneurial: new opportunities for business, job creation, innovation.

- Individual: Personal benefit in economic and income, with food production, increase market value of residences, recreation and health environment.

GI activities differ from other ones developed in the city. To begin with GI use different tools based in nature, with results in the medium and long run. They also have core or direct benefits and co-benefits, with positive externalities in the surrounding area, with free benefits for the neighborhood, such as quality environment, biodiversity, landscape, with higher market value and attraction for the settlement of families and enterprises.

GI are multifunctional while Grey Infrastructures are mono functional. For example, a road or highway is used to facilitate traffic, while green walls have impact in microclimate, air and acoustic contamination, landscape and others.

Basic questions to a GI project proposal:

- Which is the value added to the urban society?
- What services will be provided?
- Who are the stakeholders involved?
- How can the new GI project enhance the performance of the existing infrastructures (grey or green)?
- Which are the economic, financial, natural and human resources needed to develop the GI project for initial investment, maintenance, information and formation of the population?.

For GI valuation methods. (VISES 2015, page 43) we have to consider that the project evaluation should focus on the entire life project. Several barriers due to the multidisciplinary activities are involved through a long period. We may identify several dimensions in the valuation are: net benefit, market value and pricing system. Benefit may be directly economic related to market value or indirectly measured through shadow prices, with health and social wealth fare. Market value is the result of exchange transactions and may be modified by public policies or private actions with indirect shadow prices, which we associate to the property prices, such as recreation and open spaces, actually programmed or potential. The use of public recreation areas of "agrofitness" may be compared with similar services paid to a gymnasium.

Conduct

In this section we may include the behavior of persons, institutions, and organizations and their facilities and services existing in a city, which have an impact in the human life. For instant, in relation to services certain activities may cause air and water pollution, one of the serious problems in megacities, which may considered an inadequate conduct.

We know there is a harmful effect of air contamination on human health. Among the most significant impacts of polluting elements in the human beings in the EU-28 (2013) (EEA 2016) have been NO_2 (68000 persons), O3 (16000 persons) and PM2.5 concentration (436000 persons) sick.

Regarding the risk associated to daily mortality related with NO_2 concentration in Spanish cities a recent study shows that an increase of 10 mg/m^3 produces serious mortality for respiratory and circulatory causes (Linares et al. 2018).

Solutions are focused in two scenarios, to reduce the contaminant emissions, and to increase the inmission sources.

The emission polluters are mainly traffic, industry and central heating in homes and offices. To reduce traffic many cities introduce low emission zones, which limit circulation of vehicles. Industrial activities may be tackled by available techniques, special permissions and regulations. Domestic pollution from central heating may be regulated with measures addressing solid fuel burning.

The inmission sources capture and remove the polluted elements. In some way, nature may help us through urban agriculture. Plants are able to capture the CO2 from human regular respiration, and cool the atmosphere through transpiration and photosynthesis activities. Through adequate techniques, with crystalline urea NO2 may be transformed in N2 and O2 avoiding the generation of nitric acid. PM particles are also captured in the surface and roots of the plants and substratum.

Also, GI may have additional consequences of the cooling effect with change in the gradient temperature, and the air circulation fluxes, which remove the heat and contaminated atmosphere, reducing the island effect and concentration pollution.

To understand urban climate change, we have to work in several areas.

We need to expand observations (quantity, quality and type of data collected), understand climate interactions (there is a complex process as pollution or impermeable surfaces interact with rainfall and temperature), study informal settlement (by 2050, three billion people will be living in slums in bad conditions), harness technologies (digital revolution, green infrastructures will reduce flood risk), support transformations (strategies needed for resilient cities, with local innovations) and recognitions of global sustainability context (open cities to systems with global view).

As an strategy to reduce the heat island effect, we have to orientate the city behavior in several scenarios: building material, vegetation and availability of GI (Tumini I. 2012).Urban climate change has direct impact in frequent heat waves, floods and droughts, heat island and deterioration of quality environment, with health problems, reduction of wellbeing, water quality management and citizen behavior. The challenge is to bring back nature to the city to create a new environment at medium horizon (5 years) so we may appreciate personally the results. (Gonzalez-Duque J.A., Panagopoulos T 2012).

Performance

Looking for efficient performance in Urban Green Infrastructure (Young RF. 2011), urbanization process has socioeconomic impact in city environment and planning policies. It affects several scenarios; reduces ecological footprint, improves healthy environment and supplys public goods. Traditionally, the actions have been developed through local parks and urban tree planting, however new construction and botanic innovations allow to increase vertical farming in the new development at metropolitan scale. Interviews to urban stakeholders allow us to identify the failures and success in city planning projects.

To get an adequate Performance in our smart urban environment society, has to act in the corresponding Structure (S) and Conduct (C).

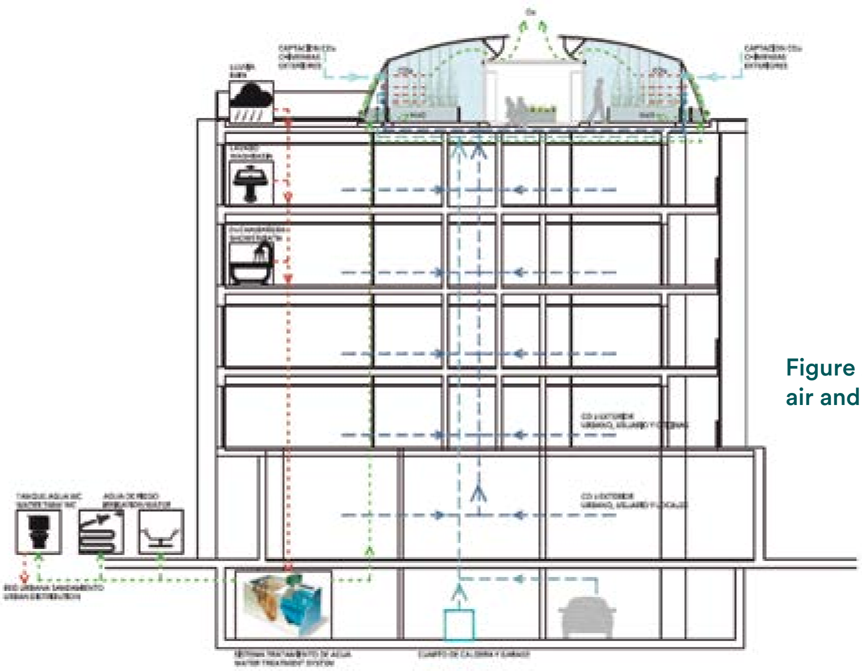


Figure 2. Building with air and water recicled

Orchard on the top at Wellington Hotel. I. de Felipe

The challenge for the expertise is to understand and identify the connections between them. Acting in the Green Infrastructure usually includes economic cost for investment and maintenance. A more efficient Conduct may requires regulation and changes in habits with sacrifice for some groups of citizens. For instance, a good quality air environment may require investment in transportation systems, central heating equipment, which causes lower contamination. Simultaneously could be new regulation for traffic in certain areas and transformation of the heating sources (prohibition of coal in favor of gas). Although there is a net benefit for urban society, some citizens will have to scarify more than others, and regulations have to consider the balance in the horizon of an urban wealth fare.

There is an opportunity to combine social and business activities with new green infrastructure planning. Madrid is a new case study with the approval in 2018 of the "Castellana Norte" project, greening the north area of the city. However, the achievement of the projects usually face some barriers such as red tape requirements, lack of coordination between policy makers, access to financial sources, as has been the case of the mentioned Madrid Castellana Norte project, with several decades of discussions. Citizens have to be informed and understand the benefit / cost ratio of the investment required, and therefore they need transparency in the process and warranty of adequate process without no legal practices or discrimination.

The performance Smart Urban Environment Change may be studied with a GLOCAL approach: Global view and Local action with specific Key Factor Indicators (KFI). Global analysis focus the attention in the Long Run, with evaluation of international project performances, evolution of temperature, forestry and farming activities, rivers, ocean and sea pollution or CO_2 concentration.

Local actions are mainly focused at city level, with parameters as temperature and humidity, air and noise contamination, circular economy, health conditions, landscape and recreation or human relationships

Goals of urban society are related to prosperity, health, wellbeing and others, in a sustainable horizon. The challenge is to design the instruments and policies to answer some basic questions of why, who, how, when and where, which has to be defined by the urban society, for improving performance in life conditions

- WHY should urban society react to the new challenges? Among other reasons, because the actual urban model in big metropolis is not sustainable. Urban life is attractive in culture, services, human relations and job opportunities. However, their environment has negative conditions, with stress, contamination, energy dependence and residuals.

- WHO are the stakeholders involved? We will say all the urban dwellers. Administration, University and research centers, professional organizations, NGO, entrepreneurs and their associations, individual persons and neighbor associations

- HOW should actors perform? Through the identification of the main problems, establishing a priority system. Defining the adequate methods to apply, combining theory and practice, evaluation, execution and follow up, technology and socioeconomic dimensions

- WHEN has to be done? After defining the goals and priorities of urban society, the next step is to establish the agenda and the timing horizon at short, medium and long run. Due to the special situation of climate change, the sooner the better.

- WHERE to develop the actions? We have to specify the city location, district, quarter,

Madrid family orchard. P.M. Contreras

building areas (wall, roof, inside, patios), open spaces (parks, streets).

We have to design a GLOCAL strategy, with a Global view of all the interaction and a local actions according the specific conditions of the area.

The Global view may be described through an Interactive Basic Matrix (IBM), where the different Performance possibilities (P1,P2...... Pi) may be related with the Conduct (C1,C2, ...Cj) and Structure (S1, S2, S3, S4,....S k) established. The process is dynamic, therefore there are different horizons to analyze, Short, Medium and Long Run. Other significant element is to consider the social preferences in relation to the Benefit/ Cost of the potential measures to be established in the population group and give priority (1, 2, 3.....)

Some of the most significant dimensions dealing with P, C, and S are as follows:

Performance: P1, air and acustic pollution; P2, Heat island effect; P3, Food supply; P4, Health and recreation; P5, local business and employment; P6, Biodiversity; P7, Biomimetisme

Conduct: C1, Regulation; C2, Education; C4, Formation ; C5, Transparency; C6, Facilities for new initiatives, C7, Synergies between stakeholders; C 8, Subsidies and taxes; C9 Agrifitness; C10, administration simplification; C11, Research and innovation; C12, Urban agriculture policies.

Structure: S1, Green areas such as walls, roofs; S2, Communication systems, roads, rail; S3, New equipment for heating; S4, Circular economy; S5, urban farming facilities.

Checking previous experiences in similar conditions and scenarios, the challenge is to identify the most significant interaction, the critical points and the best way to get sustainable solutions.

Some of the problems in the evaluation process are the heterogeneous characteristics of the elements involved. Some of them may be quantified in standard cardinal measures (economic, temperature, contamination, food, energy), while others only have ordinal evaluation (happiness, wealth fare, recreation and landscape). The performance as result of the structure and conduct need to have a follow up process, checking the results and testing with the goals established, with the possibility to change the policy and measures adopted.

We have to check each selected performance (P1, P2...) with the SWOT filter, about the Strength, Weakness, Opportunity and Threats, of each one in the applied scenario. This process may help the decision makers to

Table 3. SMART URBAN ENVIRONMENT Interactive Basic Matrix

Multifunction Scenarios	Structure	Conduct	Performance
1	S1	C1	P1
2	S2	C2	P2
3	S3	C3	P3
.	.	.	
.	.	.	
.	.	.	
n	Sn	Cn	Pn

House in Cordoba. A. Sanz

compare the different Pi alternatives. Once we have the final Performance selected, the next step is to identify the changes which should be introduced in the Conduct and Structure of each Performance.

CONCLUSIONS

In this chapter we have described some of the main interaction of climate change, Smart Urban Environment (SUE) and action to be developed. Significant dimensions of Smart Urban Environment are the positive relationship between access to green areas and longevity (Tanaka T, Nakamura K, Watanabe M. 2002). Human health include several scenarios such biological, social and psychological, therefore we have to consider no only physical but mental wellbeing (WHO. 1948). The relationship between green infrastructure, health and wellbeing is a consequence of several factors (quality environment, heat island) with biological impact. However we may consider other additional elements such as outdoor activities in recreation areas with physical exercises and social neighborhood interactions. Some activities are passive and citizens are observers of landscape or quality environment. Experiences in hospital and residence show how persons exposed to nature in comparison with those watching TV as entertainment, recover faster from stress, with lower blood pressure and muscle tension. Green areas, especially orchards and gardens, allow to do more active actions such as running, walking or farming actions. Here is where exercise is related with health (Hartin T, Mang M, Evans G.2003)

The challenge is how to convince citizens about the need to incorporate green infrastructures in our metropolitan areas. Besides the dramatic messages in the long run (50 years!) about the climate change, we should provide the arguments in favor of the immediate benefits of urban green policies. Green areas are vital for urban sustainability and create a healthy environment for recreation outdoors. Citizens may pressure developers and urban planners to include green infrastructure projects in urban political programs with special focus on financial and socioeconomic benefits. In addition, researchers have the challenge to quantify the effects of the ratio benefit/cost of the potential programs.

We should look for sustainable solutions looking at nature. There are not replications but understanding the rules of governing forms. Organic architecture use nature for design forms and connection with human beings.

Metabolism architecture focus on the idea of continuous change in biological world applied to urban environment. In this way, the city development should be related to citizen evolution.

We need to restructure urban climate solutions using new infrastructures with a potential mitigation, where nature and green infrastructures are part of the solution (Creutzig F. et al 2016)

In the coming future city, stakeholders should look for a long term research, while citizens organizations, policymakers and businessmen should work together for a sustainable horizon.

We should look at the future to identify the environment we wish but simultaneously we have to analyze the present and see what we have to do for it. (Young C, Jones R, Symons J. 2015).

Smart Urban Environment (SUE) is a progressive policy as their results may increase the wealth fare of the marginal population, usually the ones with lower green infrastructure facilities. Their actions have to be focused under a social justice scenario, where the winners (with more benefits) and losers (with higher sacrifices) recognize each other the compromise to move in a sustainable urban horizon.

BIBLIOGRAPHY

Bai X, Dawson RJ, Ürge-Vorsatz D, Delgado GC, Salisu Barau A, Dhakal S, Dodman D, Leonardsen L, Masson-Delmotte V, Roberts DC, Schultz S (2018) "Six research priorities for cities and climate change" Nature 555, 23 – 25.

Belleflamme P., Peith M. (2015). Industrial Organization. Markets and Strategies. 2nd Edition

Young C., Jones R, Symons J. (2015). Green infrastructure Economic Framework. Victoria University)

Creutzig F., Agoston P., Minx JC (2016) " Urban infrastructure choies for climat solutions "Nature climat change 1054-1056.

European Commission. DG RTD + EASME. (2018) "Who owns the right to the city? EU Research and innovation for inclusive urban regeneration" Seminar organized in Brussels October 9.

European Economic Area (EEA) (2016). Air quality in Europe. 2016 Report.

European Parliament (EP) (2018)" Urban and Periurban Agriculture in the EU" AGRI Committee PE 617-468

Ewing R, Bartholomew K, Winkelman S, Walter J, Chen D. (2007) "Growing cooler: the evidence on urban development and climate change" Urban Land Institute

Gonzalez-Duque J.A., Panagopoulos T. (2012) "Evaluation of the urban green infrastructure using landscape modules , GIS and population survey"

Greater London Authority. October (2017) Natural capital accounts for public green space in London

Hartin T , Mang M, Evans G. (2003) "Tracking restauration in natural urban field settings" Journal of Environmental Psychology 23, 109-123)

Instituto per gli studi di politica internazionale (ISPI) (2008) "Competitive cities and climate change" OECD international conference. Milan

Lipper L, K Thornton P, Campbell B, Baedeker T (2014) "Climate smart agriculture for food security" Nature climate change Review 1068-1072.

Linares L. Falcon J, Ortiz C. (2018). "An approach estimating the short term effect of NO2 on daily mortality in Spanish cities" Environment International 116. 18-28

Moulin- Doos C. (2014), "" Intercultural gardens; the use of space by migrants and the practice of respect" Journal of urban affairs 36(2)197-206)

Pitman S, Daniels C, Ely M. (2015) " Green infrastructure as life support: Urban natures and climate change". Journal Transaction of Royal Society South Australia. Volume 139, Issue 1 page 97-112.

Tanaka T, Nakamura K, Watanabe M. (2002). Urban residential environments and senior citizens longevity in megacities areas. Journal of Epidemiology and community health 56. 12, 913-6

Tumini I. (2012). El microclima urbano en espacios abiertos. Estudio de casos en Madrid. Tesis doctoral UPM ETSAM. Director Esther Higueras. Proyecto Ecourban Grupo ABIO Javier Neyla

Victoria Institute of Strategic Economic Studies (VISES) Green infrastructure economic framework. Victoria University Melbourne (2015)

World Health Organization (WHO) (1948). International Health conference NY 19-22 June

Young R F. (2011). Best practices in planning green infrastructure: Results from major US cities

París Museum. I de Felipe

CHAPTER 2

LIVING IN HARMONY WITH NATURE

Hartmut Wurster
Architect
Head of blocher partners India,
an international architecture and design firm

The blocher partners architectural team has planned a spacious leisure home development with 650 bungalows in the Indian state of Gujarat. With sustainability in mind, and using recycled materials, they are creating an oasis-like retreat whose residents enjoy a high quality of life in harmony with nature. Behind this impressive project stands a charitable organization that creates new opportunities for disadvantaged youth and brings know-how to the region.

KEYWORDS

Architecture, Sustainability, India, Using recycled and regionally procured building materials, Master planning of a holiday home development

In India's desert region near the border with Pakistan lies the city of Bhuj, in the state of Gujarat. Bhuj is known for its holy sites and its rich tradition in crafts. Just outside this flourishing city, a new holiday home development is going up on 526,000 square metres: It is to include 650 houses, a clubhouse, restaurant, pool, wellness spa, bistro and extensive sports facilities. The entire project is to be built in accordance with sustainability criteria, and using building materials procured locally.

Residents will enter through an impressive brick portal 30 metres wide and seven metres high. The gate opens to a new world: Streets lined with date palms and lush green spaces are reminiscent of an oasis; bungalows with

Farmhouse Bhuj Siteplan

four to five rooms are situated on attractive plots throughout the complex. Each of these homes offers its residents a taste of paradise on earth: The living space weaves indoors and outdoors together; covered terraces extend the living space and provide shade; generous windows bring in natural light, while shades protect against the heat. The bathrooms have their own landscaped patios, guaranteeing natural ventilation and lighting, closeness to nature, and the privacy that is so cherished in India.

Materials such as terrazzo flooring, Indian marble and teak create a warm, cosy atmosphere. The scale of the rooms creates harmonious proportions. Most of the gardens have both a swimming pool and lotus ponds. Potential buyers may choose between the five-room villas on 175 square meters of land, and the four-room villas on 140 square meters.

The bungalows are a joint project with the Indian Hunnarshala Foundation, a non-profit

organisation founded in Gujarat after the devastating earthquake of 2001. Hunnarshala, which played a major role in the reconstruction of the region, champions innovative technologies while cherishing traditional construction methods. It also promotes the exchange of knowledge, providing training to local craftsmen and to disadvantaged youth, opening up new career possibilities for them as builders and craftsmen.

The tragedy of the 2001 earthquake, in which tens of thousands died, remains seared into the collective memory of Gujarat. The new villas are designed to be highly earthquake resistant: Traditional Indian building techniques are upgraded with modern technological know-how. The load-bearing function is carried by massive, 40 centimetre thick walls made of rammed concrete, whose stability is further increased by ring beams.

The rammed concrete - a non-reinforced concrete - is mixed on site. Workers press it together layer after layer with their feet and hands. Because rammed concrete only contains 12 per cent cement, it requires less primary energy. Sand excavation is also used for the floor slab. Its warm, yellow colour harmonizes with the surroundings. In addition to its traditional look, rammed concrete has other special properties: Given its high density, it barely shrinks, doesn't crack and is not likely to change its shape.

The non-profit organisation Hunnarshala has access to an extensive store of recycled building materials, which it regularly collects, for example at demolition sites. Thus the architects were able to select materials that represent a positive ecological balance and that can be easily dismantled. The roof trusses and window frames of the villas are made of recycled wood, in keeping with traditional carpentry techniques. Traditionally hand-fired clay roof tiles - which already had protected other houses from the weather - were selected. These tiles, often eschewed in current construction projects, actually have many advantages. They are durable, easy to process, maintain and dispose of, and install: One can easily compensate for changes in the main roof construction without harming the roofing quality.

All building materials are found regionally. For the entry portal and enclosure wall, the designers used stone from a local quarry. "Bhuj Stone," with its warm colour, has been used in the region for thousands of years. Marble is also obtained locally: The bathroom walls are designed with smaller marble panels

so as to minimize waste. All leftover marble bits and dust are processed into the finely polished terrazzo floor. Not only do these recycled materials have a positive impact on the ecological balance; with their vibrant patina, they give the villas a special charm and cosy ambience.

The planners took weather conditions seriously. In Gujarat, months of dry heat are followed by a period of driving, prolonged rainfall. Generous open spaces allow water to seep directly into the ground. Canals are not necessary: Water can collect in the existing natural gullies during the monsoon season. The groundwater is protected from sinking further, and the natural water cycle is maintained. Right at the start of construction, trees were planted; by the time residents move in, these trees will provide them with shade. In addition, the massive rammed-concrete walls have a positive impact, blocking heat during the day and absorbing moisture. Large, shaded areas in front of the windows facing the gardens help keep indoor spaces cool. Cutouts in the roofing permit lush planting: Trees can grow skyward, creating a dynamic play of light and shade on the terraces.

This project proves that sustainable construction can also be financially successful. The planners' goal was to create spaces and develop an area in which people can feel good. By choosing adequate proportions and floor plans with appropriate solutions, they aimed at creating true quality of life. Well-designed spaces have lasting value and thus contribute to sustainability. The sale of these homes is off to a good start; within ten days more than 100 were purchased. Sustainability is not the sole selling point in India. Nevertheless, the planners have managed to integrate a wide variety of sustainable aspects: from the construction method to the choice of materials, the consideration for climactic conditions and integration of social responsibility, including the promotion of disadvantaged youth. Though planned as a vacation and weekend settlement, the area could find extended uses: Some of the new property owners have already expressed an interest in making this their primary residence, since the city is only 20 minutes away. The planners wanted to avoid wasting natural resources and stressing the environment. And they succeeded, through their use of recycled materials and a high degree of deconstruction capability. If everything turns to dust in 300 years, nothing will have to be carted away...

CHAPTER 3

MULTI-TIERED LANDSCAPES

Maria Auböck, János Kárász
Landscape architects

Franziska Leeb
Architecture publicist

ABSTRACT

What does it take to create lush garden on urban rooftops and in sunken courtyards? By presenting some projects from Auböck + Kárász's atelier, we will illuminate a number of aspects related to gardens adjoining architectural structures. Among them are projects with a socially minded foundation, as well as those from the "high end," which contribute to the image and value of the respective developer's project. One of the aims is to pass on knowledge that accrues with time – in the hope that the next generation can more quickly pick up the baton and become active in greening our cities.

1. INTRODUCTION

Landscape in the city occurs above and below ground level. When we are presented with a design problem regarding how to devise outdoor spaces in an urban setting, the sites are not just atop the buildings themselves but also at ground level. In the rarest instances, the site will be on natural ground. On the one hand, underground parking garages and other subterranean urban infrastructures require us to understand architectural structures and a variety of assemblies below grade on a technical level, yet they also raise – also on the theoretical-philosophical level – the question of the role of vegetation in the city. How artificial and how natural is the character of the landscape on man-made foundations to be? To what degree can the built terrain be reshaped, to what extent should nature subordinate itself to artificial topography?

A building's fifth facade, the roof, is gaining significance. The more tall buildings dots our cities, and the more common it becomes to convert attic spaces to apartments, the more the roof plans will become a pertinent factor in the "image of the city." At the same time, high density and limited ground reserves necessitate new strategies for the design of outdoor space, in which the roof landscape, as a space for shared use, holds tremendous potential to add to the available outdoor offerings, and at the same time, to create outdoor spaces with special characteristics. Both intensively planted areas and paved surfaces provide the setting for a great variety of potential gardening uses on the roof and offer exciting opportunities for residents to appropriate and even cultivate them themselves.

2. HISTORICAL DEVELOPMENT AND NEW CHALLENGES

Architecturally bound gardens are nothing new in the history of garden design. Roof landscapes are an ancient topos: the "hanging gardens" of antiquity come to mind. As far back as ancient Egypt there were terrace gardens on pyramids and roof gardens with potted plants, and from literary sources and archaeological excavations we have learned of the existence of the Assyrians' and Babylonians' gardens above ground level. The Roman Empire introduced us to "solaria," sunny, green roofs; and the "Horti Luculliani," the exotic gardens that Lucius Licinius Lucullus built on a terraced villa complex in Rome; and Diocletian's Palace in Split, which had an ivy-covered arcade on the roof, to name just a few renowned examples. Originating in the fifteenth century, a collection of holly oaks atop the Torre Guinigi in Lucca have survived to the present day. Even in in the more northern climes, gardens at lofty heights – as for example, the elaborately laid out gardens on the roofs of the Kremlin in Moscow dating to the seventeenth century or the roof gardens atop the bourgeois palaces of baroque Nuremberg – were considered good form.

Beginning in the late nineteenth century, new construction techniques such as wood-cement roofs (the forerunners of today's flat roofs) and the advent of reinforced concrete played a role in the greater dissemination of the green roof in Europe and North America. Green roofs and flat concrete roofs came to the fore through the work of François Hennebique and August Perret, and at the very latest, through the Parisian stepped-section apartment buildings by Henri Sauvage in Paris (Apartment house on rue Vavin, 1912; residential complex with swimming pool on der rue des Amiraux, 1922), the garden city had been taken into the vertical dimension.

In theory and in practice Le Corbusier was the most important proponent of roof gardens; in his essay "The Street" (1929), he described his Plan Voisin as follows: "When night intervenes the passage of cars along the autostrada traces luminous tracks that are like the tails of meteors flashing across the summer heavens. Two hundred meters above it lie the spacious roof gardens of these office skyscrapers, planted with spindleberries, thuyas, laurels, and ivy. They are gay with beds of tulips or geraniums and the herbaceous borders of bright-eyed flowers that wind along their stone-flagged paths. Overhead, electric lamps shed a peaceful radiance. The depth of the night makes the prevailing calmness but the deeper. Armchairs are scattered about. There are groups in conversation, bands playing, couples dancing. And all around are the suspended golden discs of other gardens floating at the same level."

In the nineteen-seventies, Le Corbusier's vision became a reality: Jean Renaudie and Renée Gailhoustet's design of Ivry-sur-Seine consisted of bold hybrids, in particular, stepped-section, greened building complexes. Since then, greening the city for all of its inhabitants and at all levels is no longer wishful thinking. At the turn of the twenty-first century, new requirements developed and higher expectations were made of urban green. Outdoor space interwoven with buildings is here to stay, whether these spaces be shared spaces in housing, developed and managed in participative processes, or in association with office buildings to provide an opportunity for employs to relax, and to have a positive impact on the corporate identity. The notion of a city as a gigantic coral reef upon which living beings romp about is closer to become reality. On account of climate change, cities are greening roofs to improve the micro-climate and to prevent urban heat islands.

Despite the availability of new technologies, as, for example, vertical greening or electronically operated watering systems, as well as extensive knowledge of exemplary

Globaler Hof (c) Auboeck-Karasz

projects, each new project presents us with new challenges. By presenting some examples from Auböck + Kárász's atelier, we will illuminate a number of aspects related to gardens atop architectural structures. Among them are projects with a socially minded foundation, as well as those from the "high end," which contribute to the image and value of the respective developer's project. One of the aims is to pass on knowledge that accrues with time – in the hope that the next generation can more quickly pick up the baton.

3. ARCHITECTURE MEETS NATURE

We once wrote an essay on our design strategies: "If it is architecture's task to establish a precisely defined state as permanently as possible – even if that refers to its flexibility – in landscape architecture, we always design processes." Gardens and landscapes are, on the one hand, long-term endeavors – they are open ended. On the other hand, annual and daily cyclical processes constitute a perpetual "film loop" and are thereby an expression of constant flux that is only calculable to a limited extent. A thorough study of the site, its unique characteristics, and the unpretentious matter-of-factness of its spatial, historical or social context precedes the design. Parallel to the intuitive images of a design concept, a quest for order develops, whereas architects' requests or the instructions of a competition brief sometimes tend to be more inhibiting than inspiring.

During the design process, Auböck and Kárász try to organize the desired spaces, not so much according to their function, but – similar to a piece of music – according to their dynamics with respect to modulation, we seek to develop slower and faster passages, to create spaces with different tempos and sequences, and quieter and louder parts of a garden. They are not so much tailored to specific groups of users, but rather signal different impressions, atmospheres, moods, and states of nature. On artificial surfaces, in other words, surfaces with architectural structures below them, two approaches present themselves: either to design a landscape as it might also grow on natural ground or to introduce an aesthetic that emphasizes artificiality. In any case, we always conceive of gardens such that they remain alluring throughout the entire year, yet change continually.

Vantage points and urban space

From a roof there are panoramic views that shift our perception of the city: views of the immediate surroundings, of striking works of architecture, of the urban milieu, or simply of the street down below. In the design of roof landscapes, the consciously playful approach, employing a change of perspective, is one of the most exciting challenges. Where do we direct people's attention? What will be accentuated? With a pergola, for instance, it is possible to both create a sheltered situation and to emphasize a special view. Conversely, this element can also provide privacy from the persons occupying neighboring buildings or other parts of the roof.

Moreover, roofs also offer compelling niches for experimental design. On the one hand, they are inevitably linked to salient climatic factors specific to the site, on the other hand, the question as to what will grow best and which plants have become assimilated to the habitat can perhaps be approached in a more relaxed way than when it pertains to the ground level. The foreign and the exotic can indeed flourish in some exposed locations. In the meantime, we have become as accustomed to Mediterranean plants, unusually fragrant perennials or a smattering Far Eastern exotic plants as we are to native herbs. They are a reflection of our globalized day-to-day lives – a situation in which roofs can offer a protected outdoor space for individual experimentation.

Seamless transition

On the roof of the state hospital in Hartberg (architect: Klaus Kada, 2000) there seems to be a seamless transition between the plantings and the adjoining landscape. What came about was not, in the strictest, sense a therapy garden, but rather a therapeutic field as recreational space for the patients. The green roof, which seems to hover above the landscape, is not only a formal element with a "special effect." It also situates the patients within the nature of their region of origin. Plants the patients are familiar with – from the region's gardens – reappear here in a way that shifts their perception of them. The selection was guided by a color concept: plants were chosen that have a white–yellow alternating blossom schedule in the spring, and purple–blue in the summer. It is a playful interpretation of our notions of the familiar and the foreign – both with respect to individual plants and the perceptual ordering system – eliciting a pleasurable momentary irritation.

Cracked Ice

The brief called for the design of a city square on the site of a former parking lot and above two underground parking garages in the heart of Hall in Tirol – in the immediate vicinity of a highly acclaimed hotel ensemble designed by Lois Welzenbacher (1931) and Henke Schreieck Architekten (2003). The design establishes a connection between the hotel complex and the park, which is situated three meters above the former. On the warped terrain, with limited depth available for the assembly, for the square's paving we selected in situ concrete in the form of polygonal fields with broad gravel joints.

The cracked-ice pattern obscures the topography's unevenness and is both an expression of the barrenness of the substratum and a symbol of the artificiality of this garden.

Winter garden

The lack of outdoor space on the site and the difficult location next to a raised metro line were the impetus for a 90-meter-long winter garden in a five-story, passive-technology apartment house (architects: ARTEC

Architekten, 2011). A folded steel-sheet shell reminiscent of a huge pleat forms a buffer both to the metro line and, by taking advantage of passive solar gains, to the cold. On top of that, it contains the circulation zone.

The garden develops in the airspace between the facade and the arcades, whereby four approximately 5-meter-long plant troughs are positioned on each floor. In the same alignment along the facade, this expansive winter garden is accessible via steel steps and grated horizontal platform spaces. This also ensures an appropriate air circulation. On one hand, the plantings vary between the floors, whereby on the first and fifth stories the available space allows for small trees. On the other hand, climbing plants extend over several stories. Where the lighting allows it on the north side, a diverse palette of flowering plants in white, blue, pink, and red has been arranged.

Folded garden

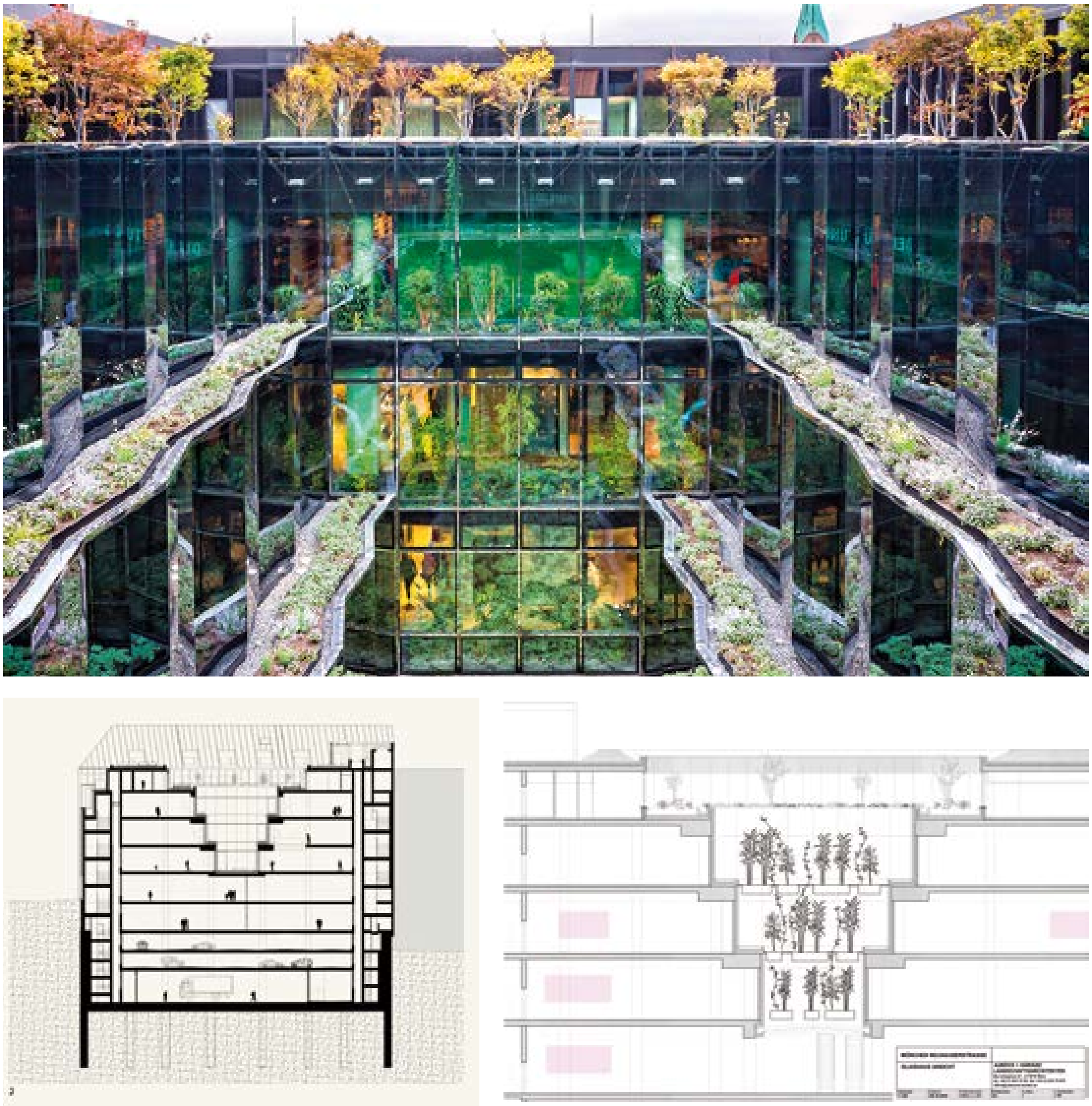
The project for the Joseph Pschorr Haus in Munich (Kuehn Malvezzi Architects, 2013), is an example of a strategy at the other end of the spectrum: a department store with luxurious apartments on the upper two floors. Here, in a courtyard surrounded by crystalline, faceted glazed facades stepping down toward the ground, the task was to interpret the architecture's essence and to create a soft and colorful landscape within a hard shell. On the courtyard's northern side rises a glass house containing bamboo, palm trees, elephant grass, euphorbia, and maracuya. The reflection of these plants creates kaleidoscope-like effects. The green, which transitions from horizontal to vertical, becomes a folded display garden, staged nature where one would not expect to encounter it – a garden as ornamental element.

Green Étagère

The notion of a multi-tiered landscape, in which the landscape and the architecture are woven together on several levels, was realized at this urbanistically, architecturally, and structurally extremely ambitious project named Erste Campus (architects: Henke Schreieck Architekten, 2015), a bank headquarters for 5000 employees located in Vienna's new "Quartier Belvedere." The close proximity to the Schweizergarten – a 16-hectare park to the east – and the gardens of the Belvedere Palace was the primary point of departure for the urban planning concept: the transparent architecture interacts with the urban space and creates a connection to nature. The expansive interior landscape is interwoven with curved forms to create an urban ensemble in which several layers of interior and exterior space flow into one another.

The forecourts consist of polygonal, directionless in-situ-concrete paving: its surface is sanded and therefore flows almost seamlessly into the interior's monolithic terrazzo floor of fine Danube pebbles. Along Arsenal Street, plane trees have been planted in gravel-covered surfaces. Above the underground garage, plane trees inhabit tree planters with ornamental grasses and geraniums. Like the concrete paving, these are framed by polygonal seating platforms.

The buildings surround four atriums holding sweet locusts, Japanese maples, as well as different perennials and ground-cover plants, as well as a garden landscape measuring 7000 m^2 interlaced with paths and a variety of islands for lounging two levels higher. This garden deck, which spans the entrance hall and the public concourse on the second story, gives the grove of ornamental cherry trees a picturesque quality. Discretely positioned pine trees provide accents that are otherwise only found in alpine settings – in order to be able to offer views of green trees throughout the year. The garden and the wood terraces are not only in the service of rest and relaxation or making a good impression on customers, but have also been adopted as outdoor workspace. Recessed seating areas provide sufficient privacy for outdoor meetings and workshops.



Joseph Pschorr. Haus Munich (c) Bayerische Hausbau

4. MULTIPLE BENEFITS

The social differentiation of the society with a wide variety of lifestyles, working at "open desks," increased mobility and offerings of a wide variety of types of dwellings all spawn an increasingly heterogeneous urban landscape that makes new options possible in urban nature. That's why the synergetic effect of superimposing planted areas that have a positive influence on the urban climate with other uses is presently an important topic. Contrasting it is Rem Koolhaas's junk-space, in other words, unkempt, poorly designed, unusable outdoor space such as residual or poorly developed interstitial spaces in the urban context. Thus, the aim is to create multi-functional, intelligently devised spaces that are well attuned to day-to-day use and can be woven into the surroundings. Versatile circulation spaces, terraced building massing, and multi-functional courtyards can remedy this deficiency and give the neighborhood a new character.

The benefit – an old expression for the communal well-being of the urban society – must also as intrinsic value be placed in juxtaposition to the real estate market's capital gains.

Urban ecology

Today roof gardens are not just places for contemplation, but can also – especially when the green roofs have intensively planted areas and use recycled materials – make a contribution to ecological design and are also an important factor in building certification.

All water-penetrable surfaces can retain rainwater – and, correspondingly, are advantages for the urban climate! Depending on the type of construction, green roofs can retain up to 95% of the precipitation. Most of this water is stowed in the substrate and evaporates; the remainder flows off with a delay. This advantage of green roofs encourages the growth of specific plant communities. A green roof whose assembly has an average depth of 45 cm has a water retention rate of about 80%, and can store about 135 l/m^2. Green roofs humidify and cool the air. This affects first and foremost the adjacent living or working spaces, but also makes a valuable contribution to improving the micro-climate in dense urban areas.

Thanks to the vegetation mass and the slowing of the air stream, the vegetation on roofs filters 10 to 20% of the dust in the air. Nitrates and other substances contained in precipitation can also be absorbed.

Modern green roof systems have very favorable thermal insulation properties and can reduce heating costs by contributing to the buildings overall thermal insulation value.

Extended apartment

The roof garden is also increasingly being given the role of the problem solver – not only with respect to ecological matters and building physics considerations. In subsidized housing, the units are becoming ever smaller to guarantee affordable rental costs. Correspondingly, to compensate for the lacking space indoors, the demands placed on outdoor spaces are increasing. It becomes a "free space" in every respect – offering children ample room to move about in and opportunities to play, and residents of all ages places to interact with each other, as also those they can withdraw to and relax in.

At the *Wohnregal* ("A Frame for Living"; architects: Geiswinkler & Geiswinkler, 2016) in Vienna's Sonnwend district near the Central Station, a subsidized housing project with a very large share of small rental flats, the outdoor spaces also take on the role of a versatile living room al fresco. This free space on ground level above the underground parking garage is a sequence of two spaces with contrasting atmospheres. A paved square, public in character, creates a passageway through the apartment block. Four round, green "inlays" framed by benches and containing perennials and ornamental grasses compensate for the inhospitableness of the streetscape and invite passersby to linger. From here one has a view to the "living-room" courtyard and play area at the heart of the complex, whose access is reserved for the residents. A grove of maple trees, ash trees, gingkos and linden trees provides vertical accentuation. Paths and lawns create a camouflage pattern that is also attractive when viewed from above. This green space continues like a carpet above the single-story courtyard building and becomes the roof garden on the first story, a more intimate space with a play area for small children.

In the context of the increase in small apartments in numerous cities, arcades, seating opportunities in the shade, green elements on access galleries, green paths atop built structures, terraces with seating, and green circulation spaces all constitute an improvement of the living environment. They create offerings of outdoor spaces with different characteristics – for instance, shady or sunny – to spend time in and help improve one's ability to orient oneself in large apartment complexes.

5. TECHNICAL ASPECTS

Let's return to the conditions we encounter when we build: Of course, the ecological value of the natural ground and the cultivated plants it hosts differs radically from that of a green roof, because on account of the assemblies, we must contend with several different layers of materials and thin soil cover. Yet when the communication process with the architects, structural engineers and HVAC planners begins early in the process and continues unabated, we do manage to create enough latitude for the garden design concept. Conversely, when the communication is poor or sporadic, it may turn out that the roof assembly is not capable of sustaining plantings. When the gardeners enter in at the end of the construction process, it is often too late to secure sufficient soil depth.

This type of interaction among all of the planners was especially successful during the Erste Campus design process. In light of the efforts to achieve slender structural members without overburdening the budget, a continuous substrate layer (which requires a depth of at least 1.00 meter) was out of the question. The thick substrate layers required for tree plantings create roof loads of up to 1500 kg/m^2, and depending on the type and size, an additional 400 to 1500 kg per tree was calculated and, where permitted by the structural engineer, recessed or raised soil with a greater depth was integrated in the floor deck with high dimensional precision. Thus, foam-glass granulate was employed to model the landscape of the garden decks, because it makes it possible to accommodate the different assembly thicknesses, and serves, at the same time, as thermal insulation and drainage layer. The trees were selected three years prior to planting and pre-grown in a flat roof ball. Upon delivery, the large trees – locust and plane trees – were about 7 meters tall and had trunks with a circumference of up to 40 cm. The height of the pines and multi-stemmed smaller trees was 3.5 to 4 meters. Provisions have also been made to anchor them: to prevent the trees from tipping over in this wind exposure, the trees were anchored with polyester mesh straps on steel reinforcement mesh below the root ball.

Depending on the building height or the height of the roof garden, wind loads must be taken into consideration. Suction forces act upon the sealing layer, which is connected to the supporting structure – whereas for intensive green roofs, these forces are of less consequence. In this case, the vertical stability of woody plants is endangered: they require specially developed anchoring.

The roof garden of the SEW academy of continuing education in Bruchsal (architect: Martin Kohlbauer, 2005) makes clear that beauty is attainable at the threshold of technological feasibility. Although the soil depth was just 16 cm, a semi-intensive garden with a refined air was achieved. This illustrates that even with a small amount of substrate and more cost-efficient forms of roof greening, alluring, picturesque effects can be attained. In a gravel-covered surface, bands of curved steel edge the heaped-up beds, which have been planted with sage, thyme, yarrow, perennials such as gorse, and, at intervals, small trees.

Heat also presents a serious challenge at sites at the very center of cities, but there are plant selections specifically put together on account of their heat resistance properties, e.g. from Mediterranean mountain ranges, which can flourish in such conditions. At the Joseph Pschorr Haus in Munich this problem is exacerbated by the strong thermal reflection of the black mirrored glazing. The courtyard on the roof above the ground floor, the roof gardens in front of the apartments on the uppermost levels, and the narrow catwalks on the levels between are all intensively planted.

Inevitably, the tops of buildings also contain technical equipment such as chimneys, ventilation shafts, and other components required for the building's mechanical systems. When working on the design of a roof, one can either simply accept them (which amounts to ignoring them), or one can view the cladding of the necessary equipment as point of departure and actively develop a wide variety of useful, unconventional spaces, or one can come up with a unique aesthetic. For the Joseph Pschorr Haus, Munich's City Planning Department required that the slanted solar panels be integrated in extensive planting. We employed dunes (made of substrate) to camouflage the panels. Organic glue kept the sedum seeding from being blown away by the wind. The pink-blossoming vegetation harmonizes not only with the brick red of the historic center's roof, but also turned out to be an urban paradise for bees.

The problem with high temperatures at the indoor garden of the passive house at Mühlgrund in Vienna didn't become apparent until it was in use. The lofty space flush with norther light offered, in combination with the automated ventilation the best conditions for the some 1000 plants, which are irrigated by means of a rainwater cistern system. Due to the region's strong winds, the ventilation sashes often did not open automatically, and as a result, heat accumulated. For this reason, the climatic concept was revised and the ventilation was programmed to take advantage of the cool morning effect, which foresees ventilation from 4:00 to 6:00 am. With regard to winter gardens, much can be learned from gardeners' experiences with glass houses!

Watering

To establish intensive green roofs, as a rule irrigation – depending on the planning concept, in different forms – will be required: for lawns and meadows (a minimum of 20 cm substrate, though 30 cm is preferable) it is recommended that sprinklers be installed for grasses and perennials (a minimum of 45 cm substrate) drip irrigation should be installed.

For roof surfaces with no slope, ebb-and-flow irrigation is an option: for roof gardens, to reduce the irrigation requirement, it makes sense to retain as much water from precipitation as possible. The drainage layer allows water with a depth of up to 60 mm to be retained; this water is available to the plants via capillary action and diffusion. Water can be retained by fitting the roof drainage system with retention elements. With the assistance of automated irrigation it is possible to maintain a minimum level of water retention during dry periods. Rainwater from a cistern or grey water can be used for the irrigation.

Lush roof gardens without irrigation are the exception today because such a situation would require continuous attention from a committed individual or an attentive group of residents.

Private harvest

Growing vegetables on roofs in raised beds is an ever-more-popular trend. Depending on the size of the vegetable garden, several water spouts and a compost pile will be necessary, and irrigation is recommended. The areas to be gardened should have an assembly with a thickness of about 60 cm, in other words, two shovels deep, to prevent damage to the roof membrane. In addition, the roof sealant must be protected from damage with a special layer (e.g., a protective mat).

The fundamental difference between the plants selected for a planting concept for a roof and one for the ground floor boils down to three important factors: knowledge of the weather conditions, the choice of substrate, and the choice of an irrigation system. When garden mounds are employed, the depth will vary. When selecting plants, one must take into consideration the sun's path, the neighborhood's specific climate, and, above all, the anticipated wind load. Generally speaking, preference should be given to robust plants that do not require elaborate care – and above all, to shallow-rooted plants. Drought-tolerant woody pioneer plants can be chosen – but with certain qualifications: we advise against those with aggressive roots, for instance, birches or willows. Plants that are good options include: smaller trees, for example, certain maples, pruned juneberries, and fruit trees.

Yet, next to a precautionary approach in response to the respective situation, special parameters can be turned to advantage. For example, the movement caused by the wind of certain plant types (for instance, ornamental grasses and tall perennials) can be highly alluring. On account of the advantageous solar path, climbing plants and fruit plants may be good options – while for the same building, on the ground level the conditions might not be so favorable.

Because roof landscapes are also used during the cooler seasons, it is worthwhile to consider using evergreen plants – even if they are scattered sparsely throughout the garden.

6. FEATURES OF MAINTENANCE

On account of the increased pressure to squeeze the maximum surface area out of residential projects, management and care of the outdoor spaces are gaining importance, whereby depending on the use, different solutions are conceivable. In housing, in many cases the care of the vegetation can to a certain degree be taken on by the residents themselves. This option is to be seen primarily in smaller projects in which the persons involved had already become acquainted with the project in a participative planning process. At any rate, the future development of a garden depends largely on its care and maintenance. This form of regular attention is indirectly part of the design process, because it has a long-term effect on the design of the garden. In this context, different control components play a role. First of all, the intended development as foreseen by the landscape architects, then how the design concept stands the test of time, the changing demands of the user and finally, the financial resources available.

Apartment buildings with amenities and the accompanying outdoor spaces (for instance, for sauna, fitness, features for children, etc.) face greater challenges regarding the management of the outdoor space as a whole. When different groups of residents use the available facilities for a variety of uses, the need for professional organization of the shared spaces – including the outdoor spaces – increases.

To guard against deterioration, roof surfaces require continual care. On account of their location, they are exposed to extreme weather conditions. When the appropriate materials are employed, these conditions can be managed. It is important that weeding is done regularly, gutters are freed of leaves, and natural seeding (by wind) of woody plants and trees such as poplars and willows be kept in check. Some civic-minded groups implement residential projects and decide to take responsibility for the lighter garden work, but hire outside firms for the heavy-duty maintenance.

Pilot project – Car-free living

It is not necessarily the budget that determines a project's success. The community's continuing success (architects: ss|plus architektur – Rudolf Szedenik, Cornelia Schindler, 1996–1999) has its roots in an intense participation process with renters who were highly motivated – both ecologically and socially. Initiated by the Green Party politician Christoph Chorherr, this pilot project arose within the framework of Vienna's subsidized housing program. Renters agreed to forego car ownership, and even promised not to use a car on a regular basis. Still, for legal reasons, for the 244 apartments, 24 underground parking spaces were erected , which, at present, are used to store motorcycles and garden equipment. The amount saved by minimizing the underground garage was invested in the shared spaces, energy saving measures, and elaborately designed outdoor spaces, both at ground level and on the roofs. The different shared spaces were discussed in work groups and then were elaborated in greater detail. The two courtyards – which, thanks to the residents' willingness to do without automobiles, are to a great extent free of underground structures – created provide plenty of variety: one, a play courtyard with a prominent hill, and the other, the pond courtyard, in which a cantilevering pier offers respite near the water. Further spaces for the community were created on the roofs. The plantings on the children's roof include: fruit plants such as quince, tart cherry, blackberry, raspberry, currant, and gooseberry. On the "living-room roof," where parties are held and barbeque grills are in use, one finds dogwood, viburnum, hibiscus, juneberry, cherry, lavender, astilbe, tiger lily and climbing roses. On the roof of the sauna, juneberry, boxwood, privet, viburnum, lavender, lady's mantle, catnip and honeysuckle were planted. Two roofs were equipped with "hill beds" (each 4 to 5 m2) for vegetable gardens. Each year the 33 planting parcels – for which a modest annual fee is charged – are re-allocated based on a precise set of rules.

There was no difficulty in finding persons to take responsibility for individual outdoor spaces and related tasks. But it became clear that staying "on the job" for an extended period of time had a positive influence on the planning process, and, conversely, that high turnover can lead to delays and misunderstandings. As construction progressed, a change occurred: the usage, care, and development of the green spaces were recognized as important topics by a growing number of future residents. The

Globaler Hof Vienna (c) Auboeck-Karasz

first generation of residents wanted vegetation with a freewheeling, prolific character – and wanted to work without assistance from professionals. Within just a few weeks of completion, the residents had planted the beds on the roof. Then they brought their own vases and vessels to the roof to make more space for additional plantings.

Globaler Hof (Global Courtyard)

The roof of the *Globaler Hof* (architect: Peter Scheifinger, 2003) was of experimental character at a time when urban gardening was not yet a household word in Vienna. This particular roof provides an inter-ethnic residential project in Vienna (accommodating 140 apartment units) with a small allotment garden. We succeeded in convincing the residents to build flower boxes large enough to put a bed in. The sheds, beds, and pergolas that sprouted tested the organizational and economic limits of subsidized housing; they were all very well received by the residents – who hail from 28 nations and watch 85 different television stations. The planting of the gardens and pergolas was left to the individual residents. As confirmed in a study dating to 2016, aside from other shared amenities, the residents identify with these gardens and they are in high demand for neighborly interaction and parties. The residents did not participate in the planning process. What makes this project thrive is the voluntary commitment of the residents, in particular of a highly committed immigrant who served as the complex's caretaker.

so.vie.so – Sonnwendviertel solidarisch (architects: ss|plus architektur, 2013) is the name of a residential project in an area currently under development at Vienna's Central Station with 124 rental apartments in which solidarity and helping one another play a central role in how everyday life is shaped. The outdoor space is an integral component of the complex's overall concept. Decisions regarding the positioning and design of certain elements – for instance, the roof garden's wood decks or the plant beds – were made with the future residents. They also had the opportunity to participate in the selection of plants – as experience has shown, the plants' development is to a large degree dependent on the commitment and involvement of individual residents. To get the ball rolling with respect to subsequent self-organization, members of a facilitator-led focus group worked together until the residents moved into the apartments.

On the long rectangular roof, which is accessible to all residents, one encounters casually arranged beds of plants framed at seating height. Their arrangement creates both a sense of expanse and places to retreat to. The ambulatory between the different areas has a wood-plank surface. On its sides, it transitions into a seating and lounging deck that conceals the piping below it. During the participation process, the residents decided against allocating the beds to individual residents in favor of a shared garden for all to enjoy. The facility management carries out the garden work of the roof garden six times each year. Not all of the plants that grow on the roof were foreseen in the garden concept. Both by means of natural seeding (carried by wind) and through the gardening activity of the residents, additional plants accumulate, whereby it requires great skill to decide which plants should be removed. Beds of plants that, with a moderate amount of professional care, in just a few years' time have developed highly satisfactorily have the potential to become a thriving, dense garden with large woody plants – which would not be the case if it were a self-organized urban gardening project.

The planting concept takes Pannonian climate (hot and dry in summer, freezing cold in winter) of the site in southeast Vienna into consideration. Grasses and perennials alternate, creating a an order that does not force itself immediately on observers, but sinks in gradually. Dwarf Russian almond (*Prunus tenella*) provide an upward thrust and are now flourishing on the rooftop. The aim of the design is not to arrive at a static appearance, but to permit a development process to take place. How this will turn out can never be fully determined in advance. It depends on numerous factors, not least of all, on empathetic residents. Beginning in 2019, a resident beekeeper's bees will inhabit the roof. With this in mind, landscape architects have provided residents recommendations on which plants to grow on their balconies: ones that will provide the bees with additional sustenance.

Five Continents

An extremely intensive participation process accompanied the realization of Wagnis ART, a residential complex in Munich (architects: bogevischs buero/SHAG Schindler Hable Architekten, 2016) – already the fifth project to be erected by Wagnis, which was established in the year 2000. This venture is located on the grounds of a former military barracks on Munich's north side, where during an interim phase, over the years Europe's largest artists' colony came into being. Beginning in 2012, to the west of the remaining artists' compound, a complex consisting of five apartment buildings named after the five continents was built; as a pilot project for contemporary forms of living, it provides spaces for both living and working. Thanks to its large share of public and shared spaces, the complex is an attractor for the entire district. The five polygonal buildings are linked by bridges on the third and fourth stories. Consequently, the unified buildings possess a variety of subordinate spaces with distinct characters and different degrees of publicness. The fields on their roofs (40 cm soil) and beds (60 cm soil) are for growing plants for the gardener's own use. The non-profit building association Wagnis considers participation and a sense of community essential to its philosophy. From the beginning, future residents were involved in the planning process via work groups and workshops, which in turn called into question the architect's autonomy. The basic disposition of the several different functions in the outdoor space was developed by a work group; they devised the mottos "At home on the go" and "Just outside the door, already there." Decisions about the positioning of the different offerings were made together. The aim to attain special "spaces with potential" is achieved by working with standard outdoor typologies that define a design framework. Within this framework there are numerous opportunities to interact and to develop versatile outdoor spaces; this was also to become an essential component of the overall design. Thanks to the participative process, those involved thought much more intensively about the future than is the case in other projects in which, at this stage, it is not yet known who the residents will be. A handbook with more than 50 pages sets forth the agreement they reached regarding rules for the use and care of the outdoor space – and thereby contributes the basis for the life of the community.

While in residential projects a number of the tasks related to care and maintenance can be delegated to the residents, in commercial buildings and office buildings, in garden matters, a competent facility management is a major prerequisite to flourishing plants and user satisfaction.
While, assuming they have a functional irrigation system and receive basic care, extensive or semi-intensive plantings – for example, the roof garden at the SEW academy of continuing education in Bruchsal testing the limits of what is technically feasible – do not require a particularly large investment, the care and maintenance of more complex and intensive green landscapes is considerably more work.

During the summer immediately following the completion of the Erste Campus, it quickly became clear that nearly ideal parameters are no guarantee that plants will flourish. While the four plane trees situated in areas above built structures were thriving, the ones in natural ground had tiny leaves. It turned out that, due to a leak that required a considerable amount of time to be located, the irrigation had been partially switched off, and the trees hadn't been watered for several weeks. The good news for subsequent projects: in the meantime, sophisticated leak-identification systems for green roofs have become available. Nevertheless, someone must be charged with repairing the leak and taking care of the plants until the system is back in operation.

No matter how refined a technical system is, it can never replace the attention and care of someone who knows and uses the garden. If, for example, an office employee notifies the property management of slug damage visible just outside his or her office window, it can take quite a long time until the facility management finds the culprit and initiates the necessary measures.

7. PARAMETERS

To make urban roofs accessible at a large scale to a building's occupants or even to the general public, it is necessary to devise a complex course of action on multiple levels. This pertains, on the one hand, to the legally

ErsteCampus Vienna (c) PeterPfau

binding aspects, such as determining what the zoning of the site is, a matter linked to the definition of the benefits to be had by the clients and investors – and indirectly, by the residents – in connection with the construction of the green roof. On the other hand, the softer topics that have more media presence or bestow a sense of luxury also play an important role. Competitions seeking designs of roof landscapes, special prizes awarded to clients who have built roof gardens, promotion of rooftop vegetable gardens, and guidelines for clients and users can all stimulate the creation of more roof gardens – not just when new buildings are built, but also on existing structures.

Planning principles and research

The presence of green has a long reputation as an important characteristic of a design, which, however, in some cases also leads to acceptance of ill- considered, kitschy solutions. Like a work of architecture, a work of garden art is a visible statement in a city and part of the urban fabric. Just because something is green, doesn't mean it's good looking. A discussion of design principles in landscape architecture is taking place within the discipline, but it doesn't reach a large audience.

Research projects on the topic roof greening and the evaluation of existing green roofs and their care concepts supply important findings that can be applied in day-to-day matters. In addition, one must take into account the motivation of developers, civil servants, and, above all, politicians. When the relevant urban development programs – which go hand in hand with subsidies and consultation – are promoted from the highest level of government, a good basis for drawing more attention to "greening the city" is created. Mayor Olaf Scholz's efforts in support of "Hamburg's Green Roof Strategy" illustrate this point, as does Paris's mayor Anne Hidalgo, whose program to promote green roofs is on track to occupy a surface area of 100 hectares by the year 2020.

The City of Munich commissioned Auböck and Kárász to make a study of the greening and sharing of roofs. This is available not only to any interested party as a stimulus to initiate the accompanying permit procedures, but also has had an effect on competitions held for large buildings: these endeavors were required to include green roofs for the use of the building occupants in the brief. In the background were offsetting transactions related to zoning: green roofs – and ideally, gardens accessible to the public – are offered as compensation for the increased profits earned on account of rezoned building heights or allowable density. If employed resourcefully, green roofs hold potential to equip densely built up cities with highly attractive natural settings.

Even if green roofs are booming – if we take a look, for example, at Vienna's roofscape, it quickly becomes clear that only a very small percentage of the roofs that have the potential to be green are green. To acquire valid data regarding how great this potential really is, in 2011, Vienna's department of environmental protection undertook a comprehensive study. The "Index of Vienna's Green Roof Potential" is accessible to one and all: one need only visit the city's online map to find out which of Vienna's roof surfaces are – on account of gentle slopes – well suited to being greened.

Planning and project management

Though in the past it was not uncommon for a landscape architect to feel impelled to reassure the architect that the plantings on the roof would not extend beyond the roofline, or, in other words, would not disturb the overall architectural impression, nowadays, attitudes have changed. Ideally, landscape architects are involved in the design process from the very beginning, and can discuss matters on equal footing with the architects and the structural engineers. What counts is that the architecture and nature become unified as one, that common goals are pursued, and that the garden and the architecture do not work against each other. Throughout the entire planning phase, landscape architects must be part of the communication loop, so that they can respond if, for instance, it turns out that the technical equipment of the roof will be significantly larger than was estimated at the beginning of the planning process, or that for structural reasons, the thickness of a certain floor assembly must be reduced. Working together in synergy, with respect to both tools and participants, is definitely an important prerequisite to creating new, ecologically sound and well-designed urban districts.

DATA

Roof garden at the state hospital in Hartberg
2000
Client: Kages
Architect: Klaus Kada , Graz
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

Cracked Ice
Main square, Hall in Tirol
2005
Client: Municipality of Hall
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

Winter garden at generationen:wohnen, Mühlgrund, Vienna
2011
Client: BUWOG Ges.m.b.H.
Architects: Artec Architekten, Vienna
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

Joseph Pschorr Haus, Munich
2013
Client: Bayerische Hausbau, Munich
Architects: Kuehn Malvezzi Architects, Berlin
Landscape architects: Auböck + Kárász Landscape Architects, Vienna
Site supervision: Kalkhoff Landschaftsarchitekten, Munich
Roof greening system: Optigrün international AG

Iles Flottantes Vienna (c) Lukas Schaller

Erste Campus, Vienna
2015/2016
Client: Erste Group Bank AG
Architects: Henke Schreieck Architekten, Vienna
Landscape architects: Auböck + Kárász
Roof greening system: Optigrün international AG

SMART-Wohnen Alfred-Adler-Straße, Vienna
2016
Client: Heimbau
Architects: Geiswinkler & Geiswinkler, Vienna
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

Îles flottantes, Vienna
2017/2018
Clients: Gemeinnützige Siedlungs-Genossenschaft Altmannsdorfand Hetzendorf / Heimbau
Architects: ARTEC Architekten / Dietrich|Untertrifaller, Vienna
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

Wagnis ART, Munich
2016
Client: Wohnbaugenossenschaft Wagnis eG, Munich
Architects: ARGE bogevischs buero architekten & stadtplaner
and SHAG Schindler Hable Architekten, Munich
Landscape architects: Bauchplan, Munich, and Auböck + Kárász, Vienna

Pilot project – Car-free living
2000
Client: GEWOG / Domizil, Wien
Architects: Architekten: ss|plus architektur – Rudolf Szedenik, Cornelia Schindler,
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

Globaler Hof, Vienna
2000
Client: Sozialbau, Vienna
Architect: Peter Scheifinger, Vienna
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

so.vie.so – Sonnwendviertel solidarisch, Vienna
2013
Client: BWS
Architects: ss|plus architektur
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

SEW Headquarters, Bruchsal/Germany
2005
Client: SEW Immobilien GmbH
Architect: Martin Kohlbauer, Vienna
Landscape architects: Auböck + Kárász Landscape Architects, Vienna

Urban orchard.
Cuba. I. de Felipe

CHAPTER 4

BIOMIMETIC LANDSCAPE THROUGH ECOSYSTEMS, MICROORGANISMS AND THERMODINAMIC PARAMETERS

Cristina Jorge Camacho
Architect, Cjcpaisaje
Cjcpaisaje.com / info@cjcpaisaje.com

INTRODUCTION

Biomimetic means learning from living organisms that have evolved well-adapted structures and materials over geological time through natural selection. Biomimetics has given rise to new technologies inspired by biological solutions at macro and nano scales. This analysis goes from microorganism scale, ecosystems scale to thermodynamic parameters scale.

The landscape architecture project of Montecelo hospital takes as reference the electrocardiogram scheme to show the vital pulse of the exterior therapy areas around the new hospital. An electrocardiogram (ECG) is a simple test that can be used to check your heart's rhythm and electrical activity. In a macro scale, this test is used to indicate the vital activity of the living beings from zig-zag lines in exterior areas to straight lines in the interior of the building. Moreover, the test involves attaching sensors called electrodes to the body. They are connected by wires to an ECG recording machine. This is linked with the maintenance and domotic system of landscape areas in order to improve the use of water, drainage and electricity.

The Landscape Master Plan of Gran Montecelo Hospital project is shown for illustrative purpose and the programme is as follows:

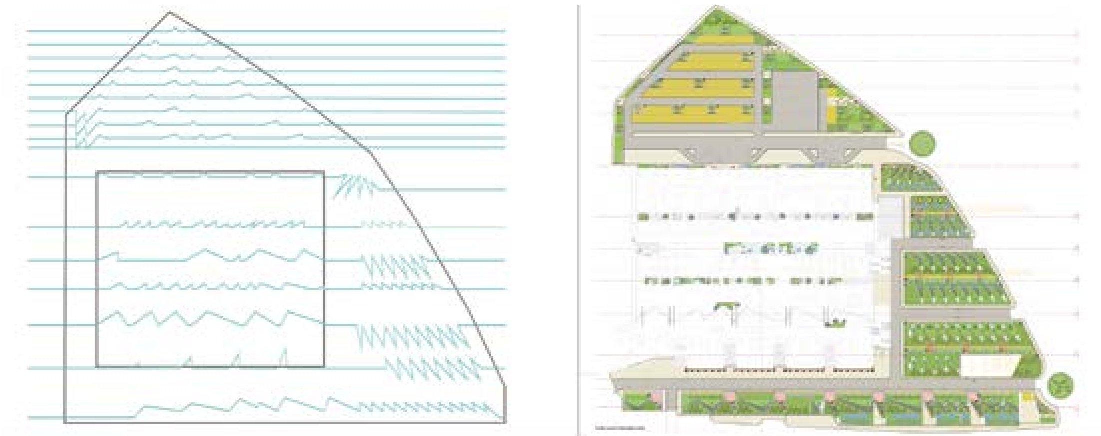


Figure 1. Scheme & Key plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

- The microscale reference of the zig-zag lines of green roof main entry plaza

- The nanoscale reference of the narrow stripes of courtyards

- The macroscale reference of the topographic bands of parks and parking

The Landscape project deals with the analysis, design and management of park, courtyards and green roof; research focusses on analyzing the microscale (animals, plants, machines), nanoscale (unicellular beings) and macroscale (thermodynamics parameters). At the same time, some areas are to lay out with a minimum of detailed spaces for activities, and do no offer anything, but necessary conditions; they are freely accessible for people of various ages who use them.

The Landscape Master Plan for the public Montecelo Hospital is composed of three primary áreas: a fringes system of main plaza, a stripes pattern of courtyards and a bands scheme of parks and parking A parallel zig-zag paving and plantation pattern connects the variety of program áreas around the hospital: a main entrance plaza with outstanding views over the Pontevedra ria, a relaxing group of courtyards among hospital programme and a therapeutic park with public parking. The zig-zag pattern significantly bends and splits in front of the hospital's main entry, helping to direct pedestrian traffic.

The landscape design blurred the boundary between interior and exterior with a linear system that extends from the interior courtyards the hospital building into series of therapeutic riparian gardens, meadows, shrublands and water system that serve a vital role in the patient healing processes.

Small organisms are composed of the essential elements, just surviving in a harsh environment. The presented landscape interventions require, at first place, electricity to activate the irrigation system and lighting equipment; at the same time, they need gravity to facilitate the drainage and accumulation of water in reservoirs; and, finally, they depend on the meteorological conditions for the process of the plant fertilization, humidity, etc. There is an invisible relationship between the living system of micro-organisms and the power infrastructure:

1	Cytoplasm:	Food uptake >	Energy Resources
2	Digestive vacuoles:	Food digestion >	Conversion Electricity
3	Shrink vacuoles:	Waste expulsion >	Emissions CO2-H2O
4	Macronucleus (a):	Feeding + Micronúcleus (b): Sexuality >	Power Stations
5	Trichocyst:	Protection	Generators
6	Cilia:	Mobility	Transmission Tower

The three biomimetics references are as follows:

1. Ecosystems biomimetics
   - Estuary (Rias)
   - Meadows
   - Temperate deciduous forest
2. Microorganisms biomimetics
   - Protozoos
   - Bacteria
   - Diatoms
3. Thermodynamics parameters
   - Temperature
   - Wind
   - Rainfall

Biomimetic landscape reveals the possibility of using balanced resources, which consist of the proper qualities and proportions of water, drainage, minerals, and electricity, need to maintain growth, such as state-of-art laboratory; they provide the option of erasing the poor soil quality. Besides this laboratory, soil poverty goes hand by hand with genuine biological riches, whether by wind or by insects as a crucial link in the ecological chain.

Circles, ovoids and zig-zag lines are nodes where lines of infrastructure converge and bands of activities concentrate. The landscape design will be affected by the impact of very mild climate weather with heavy rainfall and the difference between day-time and night-time temperature; so far away of the desire to impose order such as geometry in nature which is rare, and usually temporary. For example, concentric circles are created by sand crabs after high tide on the beaches of Bali, Indonesia or by circular frog ponds. Landscapes are dynamics like the result of physical processes (such as erosion and sedimentation) and of biological processes (involving growth, blossoming, and decay). It is significant the arrival of volunteer plants and the remarkably dynamic way in which plant species intercross and the role of insects and animals in such developments.

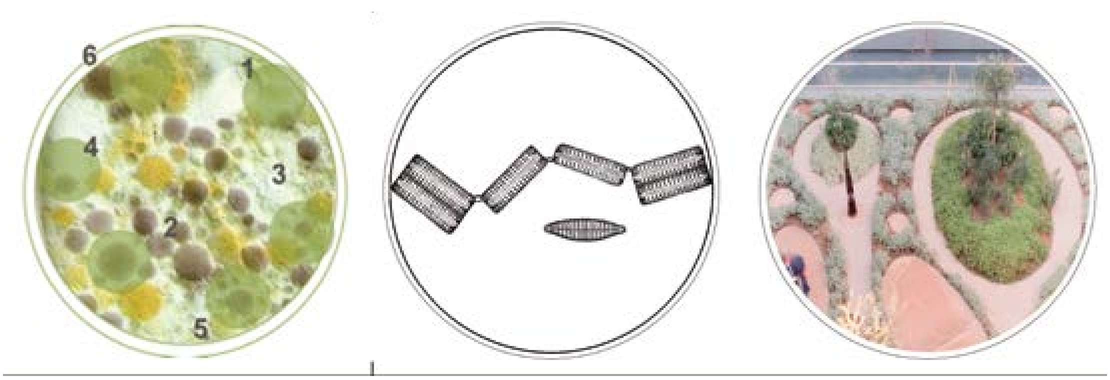


Figure 2. Microorganisms components & Green roofs islands. BELLMAN / HAUSMANN/ JANKE/ SCHNEIDER, 1994: Invertebrados y organismos unicelulares, Ediciones Blume, Barcelona.

1. ECOSYSTEMS BIOMIMETICS. MICRO-SCALE. TYPE OF LANDSCAPE: ESTUARY, MEADOWS AND TEMPERATE DECIDUOUS FOREST (THE QUALITY OF MATERIALS)

Microscale. Ecosystems biomimetic

Humans, animals, plants, and machines. The scale is related to the research of sense of diversity such as fractals are any of class of complex geometric shapes that commonly exhibit the property of self-similarity and a self-similar object in one whose component parts resemble the whole.

Ecomimetics refers to the design of artificial landscape that mimic ecosystem processes and functions. This approach provides potential opportunities for climate change adaptation and mitigation by optimizing the use of resources in the exterior áreas around the hospital.

The Gran Montecelo Hospital sits at the end of the rias bears its name, occupying the valleys of the Lérez and Tomeza rivers. Pontevedra extends southwards to the mouth of river Verdugo in Ponte Sampaio. It is surrounded by four mountainous regions divided by two faults stretching north-south and one from northeast to southwest. Galicia is one of the more forested areas of Spain, but the majority of Galicia's plantations, usually growing eucalyptus or pine, lack any formal management. Massive eucalyptus plantations are largely on behalf of the paper company

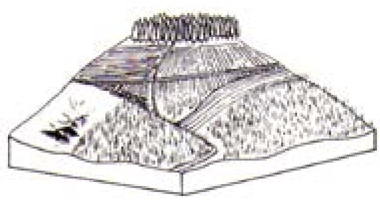
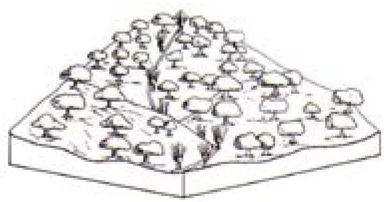
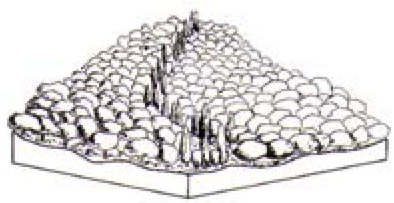
The Marine Ecosystem Estuary-Rias Bajas	
The Grassland Ecosystem Measows-Praries	
The Forest Ecosystem Temperate Decideous Forest- Hills	

Figure 3. Ecosystems biomimetic schemes: Estuary, Meadows, Green hills

Empresa Nacional de Celulosas de España (ENCE), Pontevedra which wanted it for its pulp.

• **Marine ecosystem (Estuary-Rias Bajas)**

It is an approach to the riparian vegetation dynamics. The estuaries (the so-called Rías Bajas) are unique systems which show a gradient of vegetation from the open marine coast to the inner shallow estuarine waters. Around ENCE Factory, the source of pollution a nearly abiotic área was found where only some sulfur bacteria lived. Macrophytic vegetation increased with increasing distance from the point of discharge. The roots of riparian trees and shrubs help hold stream banks in place, preventing erosion and they also trap sediments and pollutants, helping keep the water clean. Moreover, riparian vegetation provides habitat for many land-dwelling creatures such as birds and lizards to find shelter, food and water and it shields river from summer temperatures extremes. The cover of leaves and branches brings welcome shade, ensuring that the stream temperature remains cooler in the summer and moderate in the winter (+23C/+6,3C in Pontevedra).

• **Grassland ecosystem (Praries- Meadows)**

Grasslands are located in temperate regions and the área mainly comprises grasses and a little number of trees and shrubs. Prairies is a temperate grassland. It is a field where the agricultural and animal production area conditions the surroundings. Apart from the perpetual meadows, they are often conceived of as artificial or cultural habitats, since they have emerged from and continually require human intervention to persist and flourish, but they are really semi-cultural habitats because of the actions of intensive but invisible grazing by grasshopper and other insects in normal weather conditions. In summertime they are converted in desert meadow restricted by low precipitation or lack of nutrients and humus; while, in springtime, they often host a multitude of wildlife, providing areas for courtship displays, nesting, gathering food or sometimes sheltering if the vegetation is high enough. Spring meadows support a wide array of wildflowers, which makes them of utmost importance to insects like bees, pollination, and hence the entire ecosystem. By contrast, the agricultural meadow that replaced the formerly cultivated field changes little from year to year. Galicia is notable for the extensive surface occupied by meadows used for animal husbandry, above all cattle, an important activity.

• **Forest ecosystem (Green Hills)**

It is a mild topography with a density of scrubs and a small forest. They are the ecosystems in which an abundance of flora is seen so they have a big number of organisms which lives in relatively small space. Temperate deciduous forest is located in the most temperate places as Pontevedra that have sufficient rainfall. Summers and winters are clearly defined and trees shed the leaves during the winter months.

The zig-zag lines of green roof main entry plaza. On Earth biomimetics

The green-roof design in front of the hospital's main entrance. Instead of planting sedum carpet in an extensive green roof, as it is used to do, the green roof triangle áreas concentrate energy resources. On the green roof, there are fruit and aromatic trees located on small earth mounds covered with shrubs and herbaceous plants which have a special structural reinforcement. The selected plants are adapted to medium temperatures of Pontevedra with 16 ud/m2 density, in tray fillers 5cm thick. The localized irrigation has an automatic drip watering system and there is a drainage network of water tanks under these triangle mounds.

The sustainable water system pay full attention to hydrological cycles and the prevention of erosion by an automatic drip in localized

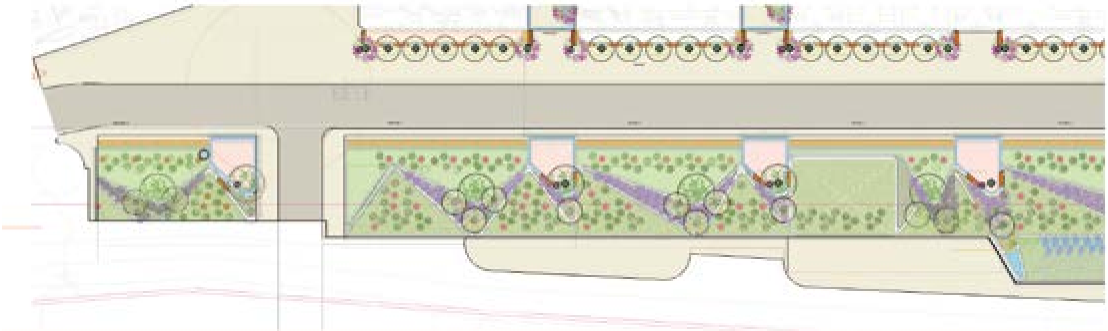


Figure 4. Fringe 1 of Green roof Plaza plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

Figure 5. Fringe 2 of Green roof Plaza plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

irrigation system. Transmittance: 0.26 W/ m^2. The hybrid between extensive and semi-intensive green-roof is a more complex system and allows for the inclusión of perennials, small shrubs, and trees in pots in the plant selection. The large capacity of the drainage and water retention layer by gravel stripes is located perpendicularly to the roof slope (10-45%).

The quality of materials

Should the raw materials that improve soil quality be endogenous or exogenous? The landscape intervention in the Gran Montecelo Hospital can be read as a trinary landscape in which the dark of the temperate deciduous forest, the light of estuary and the twilight of meadows share the territory more or less equally.Triangular islands such as porous spots inside hardscape areas are spread. In other disciplines, some economic variables are determined by models, while others are usually assumed to be determined by factors outside of the model. The former is called endogenous variables and the latter exogenous variables. The analysis of distance and area combines to regulate the balance between the endogenous and exogenous species1.

• **Endogenous material**

Endogenous zig-zag islands. The materials are deciduous trees, aromatics plants, and herbs. The "landscape skyscrapers" works with vertical layers which concentrate resources instead of spreading them on horizontal surfaces. Indeed, what we contemplate is an archipelago of islands of small forest put among meadows and hills. Isolates spots concentrate their energy resourses such as survival landscape for humans, animals, and plants. Endogeneity refers to the recipient of DNA, usually in prokaryotes, which are organisms without a cell nucleus or any other membrane-bound organelles. Likely, in islands landscape such as in super-tall buildings, which historically have focused on structural challenges (resisting gravity and lateral forces from seismic and wind), the rules have changed, and energy has become the defining parameter, because of tall buildings alleviate infrastructure and transportation energy losses by consolidating commune routes, reducing thermal transfer surfaces and encouraging central development with mass transit options like islands.

- **Exogenous material**

Exogenous continents. The materials are humus-rich earth, sand and gravel among stripes. Due to the proximity of the estuary and the windy weather, many seeds come from the estuary and that is the reason why there are layers of humus-rich earth underneath the entire unpaved ground and not only under green areas. The initial geometry of islands will change into great continents depending on the wind and the final configuration will be as complex and unpredictable as original rural landscape. The intention is similar to the plan of removing tons of sand from desert areas which will leave depressions to be filled with water, where algae can be grown to provide sustainable sources of energy. As well as to erase the notion of ghettos or micro-nations which are externally alienated and internally homogenized extraterritorial enclaves, spaces of legal void or strategic implants2. This mainly concerns those regions in the world which are and will remain remote from central energy supplies, or are thinly populated or are islands that cannot for economic reasons be connected to a power supply. In the project, the process is reversed because of the islands are owned of energy supplies (water, drainage, minerals, and electricity). Exogenous means something derived or developed from outside the body; originating externally. Ectosymbiosis os symbiosis in which the symbiont lives on the body of the host. Eukaryotes are organisms whose cells are organized into complex structures by internal membranes and cytoskeleton and the most characteristic membrane-bound structure is the nucleus.

2. MICROORGANISMS BIOMIMETIC: NANO-SCALE: PROTOZOOS, BACTERIA, DIATOMS, (THE WASTE MATERIALS)

Nano scale. Microorganisms Biomimetics

The nanoscale is the scale of the objects smaller than a cell and bigger than an atom, those which cannot be easily seen without aid. In physics, the nanoscale is sometimes considered the scale between the microscale and the atom scale.

- **Protozoa**

Eukaryote reference: Protozoa are usually single-celled and heterotrophic eukaryotes containing non-filamentous structures that belong to any of the major lineages of protist. Cilia have their body ovoid to elongate, an uniformly ciliated. Many protozoan species are symbionts, some are parasites, and some are predators of feces bacteria and algae. Exogenous means something derived or developed from outside the body; originating externally. Ectosymbiosis is symbiosis in which the symbiont lives on the body of the host.

- **Bacteria**

Prokaryote reference. Bacteria constitute a large domain of prokaryotic microorganism and have a number of shapes, ranging from spheres to rods and spirals, without a cell nucleus or any other membrane-bound

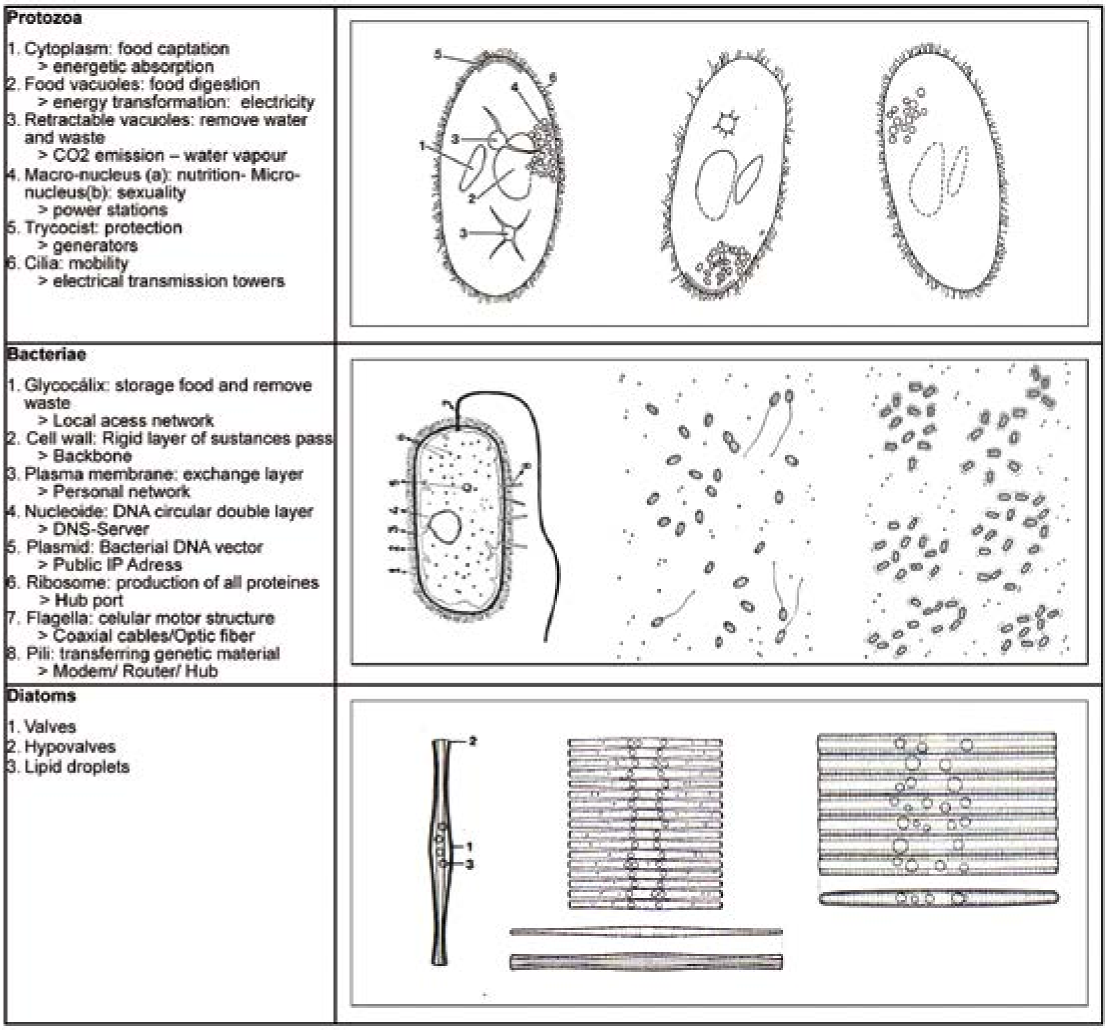


Figure 6. Microorganisms biomimetic scheme. BELLMAN / HAUSMANN/ JANKE/ SCHNEIDER, 1994: Invertebrados y organismos unicelulares, Ediciones Blume, Barcelona

organelles. They also live in symbiotic and parasitic relationships with plants and animals and have a few micrometers in length. Bacteria provide the nutrients needed to sustain life by converting dissolved compound such as hydrogen sulfide and methane to energy. Magnetotactic bacteria produce their magnetic particles in chains, where prokaryote genes are also expressed in groups, known as operons, instead of individually as in eukaryotes.

- **Diatoms**

Algae Eukaryote reference. Diatoms are unicellular and can exist as colonies in the shape of ribbons or filaments such as Fragilaria crotonensis, fans, zigzags or stars. They are producers within the food chain and are enclosed within a cell wall made of silica (hydrated silicon dioxide) called a frustule. Their cells are containing within a unique silica cell wall comprising two separate valves (or shells). One of the valves is slightly larger - the hypotheca- than the other -the epitheca- allowing one valve to fit inside the edge of the other. Diatoms communities are a tool for monitoring environmental conditions, past and present, and are commonly used in studies of water quality and in researches in nanotechnology.

The narrow stripes of courtyards. Underground biomimetics

Series of enclosed pieces of ground which represents the relationship between nature and culture has a multifunctional courtyards build-up with high water retention capacity for lawns, perennials and on deeper layers of growing medium for shrubs and even trees. The passing of time can be perceived in the wider landscape, but also in every garden.

The system of on-ground gardens and intensive green roof gardens allows to creates a microclimate, reducing exterior temperatures and improving air quality, including thermal benefits as vegetation covering which gives additional climatic protection for spaces located underneath them. A substrate of humus and river sand is sprayed on in layers 50-100cm. Courtyard induces natural ventilation, optimizes lighting and promotes energy saving. The drainage system has been designed considering the proximity of the groundwater table and the presence of sandy clay in the subsoil.

The waste materials

What does the definition of waste mean in relation to wildness if this concept means the preservation of the world? Does bad weed translate the definition of waste into landscape projects? Gilles Clément identifies three kinds of spaces which he believes have the potential to allow our biodiversity to continue to develop: délaissés or transitional

Figure 7. Strip 1 of Courtyards plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

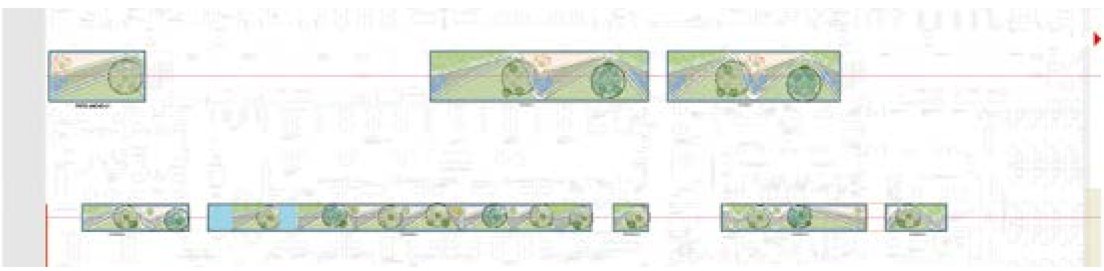


Figure 8. Strip 2 of Courtyards plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

spaces -formerly exploited as agricultural, industrial, urban or touristic space and it is synonymous with the notion of untended or fallow land-, réserves or undeveloped spaces -a place never exploited, whether by change, or because physically inaccessibility makes it too costly to develop-, and ensembles primaries or officially preserved natural places -land or space set aside and protected by administrative degree 3. He makes no distinction between "good" and "bad" weeds; their intermingling is determined by a biological process that defines their position and their appearance. With the usage of raw materials that in the end return to mother earth, the concept of "waste-free" was actually realized, where plantations are grouped into clumps of the earth such as small groups of immune cells that act as filters for the lymphatic systems.

In reference to this biological wildness, Peter Sloterdijk offers a reflection on humanism as the effort to tame the human beast.

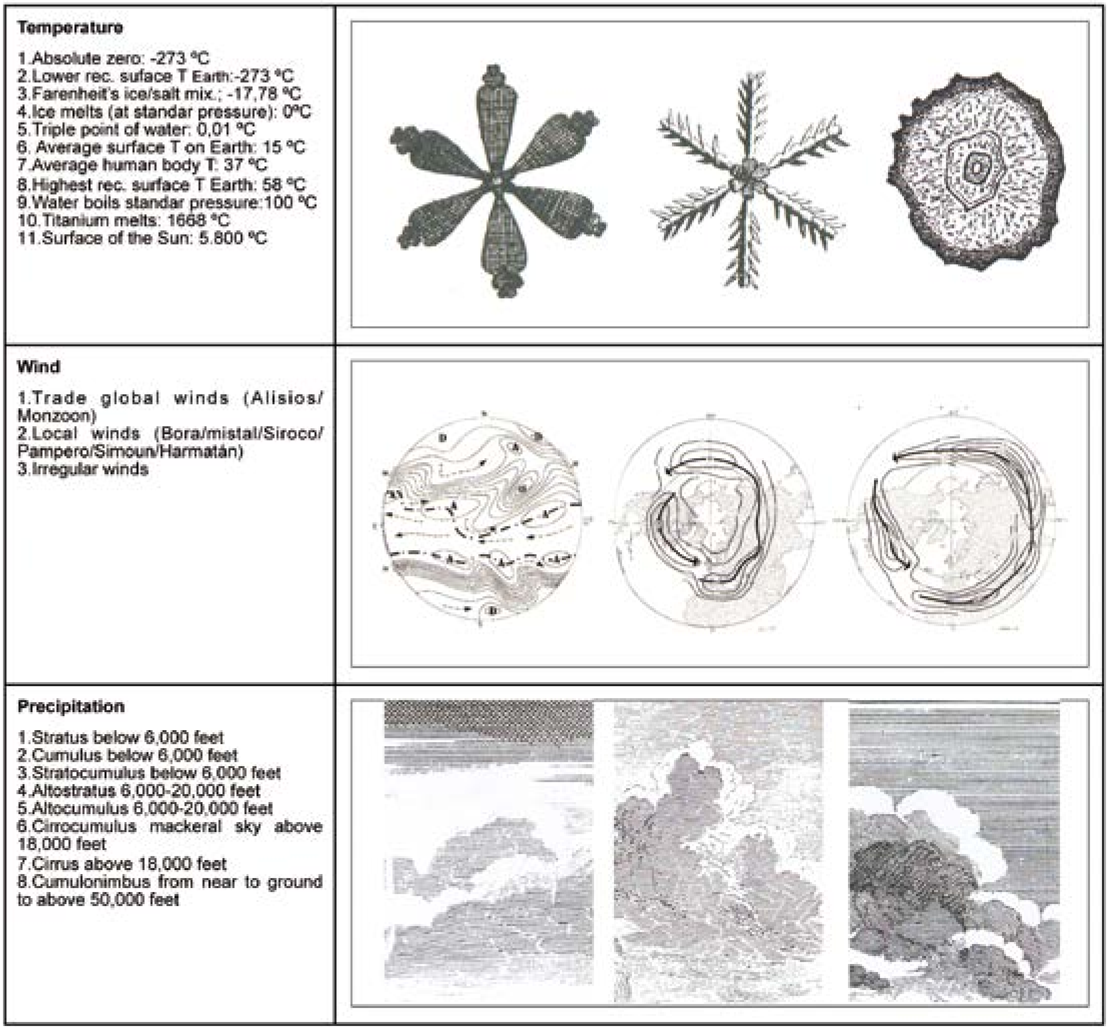


Figure 9. Thermodynamic and climatic parameters. Diccionario Enciclopédico Hispano-americano de Literatura, Ciencias, Artes, etc., Barcelona, (1887-1899), apéndice (1907-1910)

Consequently, he proposes the creation of an "ontological constitution" that would incorporate all beings (humans, animals, plants, and machines) 4. It is a description of the self-domestication of humans. Indeed, by suggesting that one could even go as far as to define a human as a creature which has failed in being and remaining an animal. The definition of waste may be the undeveloped plot or leftover fragment of soil, and they could be a refuge of the earth's biodiversity and it inevitably affects to some wasted space that awaits a future use. It is no longer a place abandoned to rubbish and weeds but becomes a sort of reservoir or biological time resource for the future. The wastelands are fallow fields, roadside shoulders, peat bogs and moors. It is the protection of wildlife as a microbiological chain.

3. BIOMIMETIC MACRO-SCALE. THERMODYNAMICS PARAMETERS: TEMPERATURE, WIND, HUMIDITY (THE DELIVERY TIMES OF MATERIALS)

Macro scale. Thermodynamic biomimetic

The macroscale is the meteorological scale covering an area ranging from the size of a continent to the entire globe. The smallest scale of meteorological of phenomena, called microscale, that range in size from a few centimeters to a few kilometers: net radiation, sensible heat flux, latent heat flux, ground heat storage, and fluxes of trace gases important to the atmosphere, biosphere, and hydrosphere. It also refers to small scale meteorological phenomena with life spans of less than a few minutes that affect very small areas and are strongly influenced by local conditions of the temperature of terrain. Thermodynamics parameters in Pontevedra (20 m High, 42.433619° N, 8.648053°W) are: Temperature (Tmax= +29°C/T°Min= +6,3°C) / Wind (VMax=153 W summer/E winter) / Precipitation (1,613 mm/year) / Humidity (HR Anual= 69%)

- **The temperature**

Thermodynamic temperature is defined by the third law of thermodynamic in which the theoretically lowest temperature is the null or zero point. It is often also called absolute zero (-273°C). At this point, the particles constituents of matter have a minimal motion and can become no colder. This absolute temperature does not depend on the properties of a particular material. From a microscopic viewpoint, material is at thermal equilibrium if the quantity of heat between its individual particles cancel out.

- **The wind**

The thermodynamic characteristic of wind means that the wind is affected by air temperature and pressure and has an effect on wind turbine performance -in terms of energy- based on wind chill effect and Bernoulli's equation. The wind chill effect leads to temperature differences that enthalpy and entropy components must be considered into the thermodynamic analysis. The wind pressure effect based on Bernoulli's equation affects the entropy of the wind.

- **The rainfall**

The rainfall occurs after agglutination of water droplets with condensation nuclei, the size of the particle formed by the condensation nuclei connected with a droplet of wáter increased considerable and caused to fall. There is another thermodynamic explanation. The clouds are gas composed of dry air and saturated water vapor whose optical properties depend on temperature. When the temperature of the cloud decreases, the color of this gaseous system tends towards white 5.

The topographic bands of parks and parking spaces. On the Air biomimetics

The Landscape Project for the Gran Montecelo Hospital divides the surface area into specific stripes to identtfy improvement strategies evaluating thermodynamics imbalances such as improve facilities, increase biodiversity, reduced the flooding effect and the relationship between radiation, humidity and wind conditions along the year. The advances in the knowledge of energy behavior applied to different shapes, materials and construction techniques and the improvement in the simulation software of thermodynamic phenomena are useful macro-scale tools.

In park areas, some changes can occur suddenly: discontinuities may disrupt the course of certain events, creating a complex situation whereby dynamics change take place at different speeds, something that is often difficult for the individual observer to grasp. The rural and urban park areas are also combined with other functions: paths, playgrounds, adult games, squares, car park, and helipad. The car park has triangular islands among parking places and is specifically designed to be applied taking account of the singular topography and several green bands are designed in order to prevent and filtrate water runoff.

The delivery times

How could be delivery times on construction sites where livings beings (plants animals or humans) are growing? How can establish these delivery times if every living thing has the capacity to transform, either by choice or by necessity, over the course of its life, and whatever evolutionary change occurs is passed on to the next generation? The fundamental processes, namely dispersal, invasion, competition, adaptation, and extinction, are among the most difficult in biology to study and understand 6.

Robert Le Ricolais said that together with life comes the problem of growth, and until now man has not been capable of making machines that grow 7. On the other hand, it is important the principle of automorphism such as some kind of geometric assemblage of forms which go into one another, repeating themselves. Some microorganisms such as radiolaria are a highly elaborate piece of work where you have a ball inside a ball inside yet another ball. Radiolaria is distinguished by the segregation of their soft anatomy into the central

Figure 10. Bands 1 of Parking plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

Figure 11. Bands 2 of Parks plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

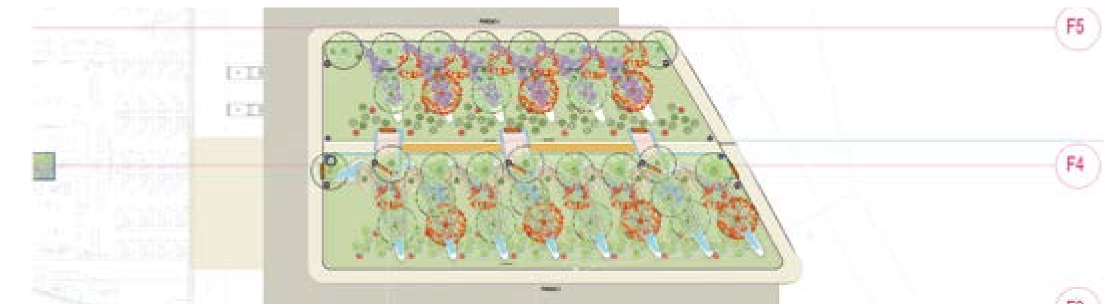


Figure 12. Bands 3 of Parks plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

capsule, containing the endoplasm, and the surruonding ectoplasm and by the siliceous, opaline skeletons of the large majority of species. In addition, Buckminster Fuller traced his observations back to the concept of evolution, essentially proposing a dynamic system, a chain of consecutive reactions (such as a microorganisms chain) in which a bird, for example, modifies its habitat the moment It builds a nest, but in due course, the environment transforms the bird's behavior and existence, just as it has transformed humans in many respects 8. About delivery times, some thoughtful approaches for the future are alternated between the utilization of state-of-art technologies and no technology at all, between seeking total control of the environment and abandoning all modes of control.

CONCLUSIONS

An important role in sustaining bio-diversity is played by nature reserves scattered like islands over an agricultural landscape. In relation to lean construction and urbanism, Toyota System Production (TPS) defines Lean such as an operational strategy oriented toward achieving the shortest possible cycle time by eliminating waste; in other words, pull

Figure 13. Bands 4 of Parks plan. Montecelo healthcare landscape. Architectural project: Chile15 arquitectos, Landscape project: Cjcpaisaje

versus push, where pull is simply providing a product or service only when asked for by the customer and push means a product is produced and then sold to a customer.

1. Ecosystems biomimetics. Micro-scale references. The green roofs.

The quality of materials. In relation to the material management system: The lean system applied to landscape architecture talks about the use of proven material management system and visual aids by adding signs and by organizing tools and equipment on the projects. The qualities in lean urbanism are: sort, store, shine, standardize, sustain. The heterogeneous materiality of the project assures a cycle system; one could be sort, shine and standardize and the other, store and sustain. Firstly, the endogenous materials are the part of semi-intensive triangular green roof islands which can be set on a small mountains of certainly 600-800 mm for shrubs until an altitude of approximately 1000-1200 mm for trees; secondarily, the exogenous materials are the part of the extensive humus earth roof which can be set on a growing medium layer of approximately 100-150 mm where a low weight and low maintenance cost are stipulated. Ecosystems cannot exist within isolated areas, but must instead be part of a larger environmental framework, an interconnected pattern of natural areas that allows plant and animal species to migrate 9. Existing nature triangular islands are therefore being expanded, and new ones laid out and connected by corridors of varying width such as zigzag stripes of humus-rich earth.

2. Microorganisms biomimetic. Nano-scale references. The courtyards.

The waste materials. In the lean system applied to landscape architecture the waste elements are motion, transporting, overproduction, inventory, waiting, overprocessing and defects. If we consider time in relation with movement and growth, seed movement coming from the river are transported by the wind as well as traveling plants, worms, insects or humans passing through and germinate wherever bare ground welcomes them into the park, the garden or the green roof; and this approach relativizes the notions of plants and weeds. When a tree grows and coves with shadows the soil behind it creates an island of green. At the beginning the shape of the island was predetermined but as the times goes, this form blurring its contours in the natural process and takes shape not only on a drawing plan, but on the site; supporting a weed network such as a fabric or structure of cords and wires that cross at regular intervals and are knotted or fixed at the crossing 10.

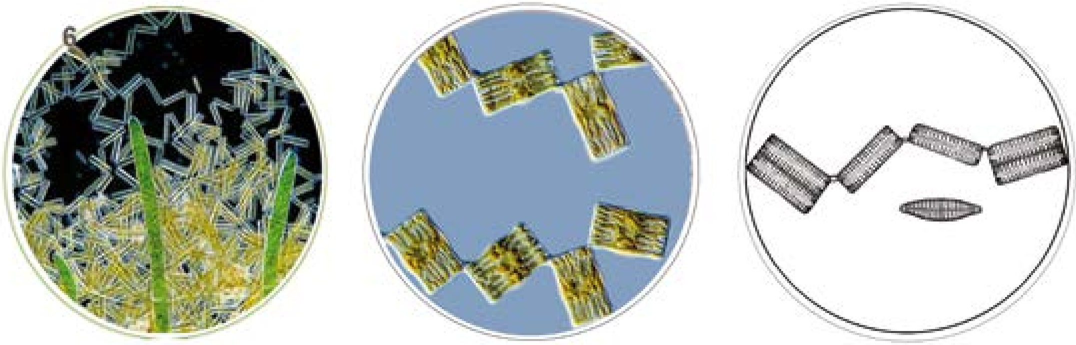


Figure 14. Zigzag Diatoms. Microorganisms components & Green roofs islands. BELLMAN / HAUSMANN/ JANKE/ SCHNEIDER, 1994: Invertebrados y organismos unicelulares, Ediciones Blume, Barcelona

3. Thermodynamics parameters. Macro-scale references. The parks

The delivery times of materials. Referring to lean construction, long term decision making are long term improvements even at the expense of the short gains could be made using easier or less expensive decisions; create continuous flow in every process such as systems need to be linked together to allow communication and elimination of the waste in the overall system by embracing technology and by using proven technology to improve communication. In the same way as Zero Energy Building (ZEB) creates a heterogeneous indoor environment in the office space, for example, where it would be acceptable to have differences in the quality of workplace space and environment; the Green roof it would be a heterogeneous place where it is possible to use the concept of artificial ground and the idea of enjoying environmentally-friendly space that, over time, reflect the changing nature outside in relation with seasons is beneficial. To make a hybrid of passive and active techniques is difficult, but more precise and advanced control technology makes this possible 11. The delivery time is strongly linked to the maintenance time, whose by means of an archipelago of triangular islands such as a dendritic structure together with the proved management, the protection, and expansion of island configuration versus continent landscape. Should not only help improve biological diversity but also maintain a humidity level below the layer of leaves, branches and weeds from the changing seasons. The system is like the immune system's first line of defense. Analyzing the proximity of the estuary in the project, the hydrographic network is dendritic too, where water flows on a seasonal basis through the watersheds of the estuary.

NOTES

1 *"The equilibrium model of island biogeography explained variation in number of species on islands by the influences of isolation and area on rates of immigration and extinction. Firstly, this model predicted higher rates of immigration to islands nearer sources of colonist and, secondarily, the model predicted high rates of extinction on small islands". McArthur, Robert H. / Wilson, Edward O.: The Theory of Island Biogeography. Princeton University Press, New Jersey, 2001.*

2 *"The idea of "island" as an urban metaphor can also be understood as a real laboratory of resource management or sustainable uses of resources that can facilitate the elimination of poverty. Just like an island in the sea, the management of resources such as water, sewage, food and, energy is the key for the sustainable future of the cities where this tensión between*

formal and informal has become a central issue. We can describe economic (price of oil) as a subset of culture, as a system for managing and developing our resources whatever they form." Islands + ghettos. Catálogo exposición, Heidelberger Kunstverein, 2008.

3 "Clément defined the notion of the "Third landscape" in 2002, in the context of a study of the area Valssiviére-en-Limousin in France. He identified transitional or unused spaces, undeveloped land, and officially designated natural places as fragments of the planetary garden which have the potential to ensure the future of earth's biodiversity." Gilles Clément / Philippe Rahm. Environ(ne)ment. Catalogo Exhibition, Centre Canadien d'Architecture, Montreal, 2007.

4 "Anyone who is asking today about the future of humanity and about the methods of humanization wants to know if there is any hope of mastering the contemporary tendency towards the bestialization of humanity" SLOTERDIJK, Peter. Normas para el parque humano. Siruela, Madrid, 2000.

5 Mbane Biouele César: "Fundamentals on Thermodynamic Processes behind Clouds' and Rainfalls' Formation". Atmospheric and Climate Science, 2015, 5, 257-265.

6 "The number of species found on islands far from the source colonization will grow more rapidly with island area than will the number on near islands. The number of species on large islands decreases with distances from the source of colonization faster than does the number of species on small islands" McArthur, Robert H. / Wilson, Edward O.: An Equilibrium Theory of Insular Zoogeography. Princeton Univ. Press, New Jersey, 2001.

7 In his 1940 article on "Systemes Reticules..." Le Ricolais reveals some further characteristics of the rapport between forms. Within the natural form of the radiolarian there are two majors structural systems an internal scaffolding of skeletal polyhedra (Le Ricolais "triangulated" frame), which is a topologically closed system in compression- organized for stability and performance; and an external surface membrane that is a topologically open system in tension. The systems are separated or joined by an epidermic layer of radiating pseudopodia (or spicules) in compression. Its most apparent characteristics are the separation (by diaphragms) of the compression zone from the tensile zone, and that both zones are optimal structures for their loading. Robert Le Ricolais. Visiones y Paradojas. Fundación Cultural COAM, Madrid, 1997.

8 Fuller's Franklin Lectures in Science & Humanities, presented at Auburn University in 1969, was published in R. Buckminster Fuller, Eric A. Walker, and James R. Killian, Jr., Approaching the Benign Environment, ed. Taylor Littleton (London: Muller Limited, 1973) p.4.

9 "Island do not need to be surrounded by water: an isolated copse, or an enclosed farmstead in an open landscape, can effectively be an island in the space surrounding it. In ecological theory, an important role in sustaining bio-diversity is placed by natural reserves scattered like an island over an agricultural landscape." VROOM, Meto J. Lexicon of garden and landscape architecture, Birkhauser, Basilea, 2006.

10 "The system depends first upon the sun, the net production of photosynthesis after respiration, upon the water and upon the cycling and recycling of the materials in the system by the decomposers. it is quite clear that the process requires that the substance or wastes, the output of one creature, are the import or inputs to the others. The oxygen wastes of the plant were input to the man, the carbon dioxide of the man input to the plant; the substance of the plant input to the man, the wastes of the man input to the plant; the wastes of the man and the plant input to the decomposers, the wastes of these the input to the plant; and the water went round and round and round." McHARG, Ian L. Design with nature, The Falcon Press, Filadelfia, 1971.

11 *"The ground surface of modern cities is blanketed in asphalt and concrete. It is necessary to limit coverage to a minimum. Where concrete and the like are absolutely necessary, it is important to have a shift toward permeable and absorbent materials." MATSUNAMA, Katashi. "Toward the realization of ZEBs". En: Sustainable Architecture in Japan. The Continuous Challenge 1900-2010 & Beyond Editorial Board Members of Nikken Sekkei, Tokio, 2010.*

BIBLIOGRAPHY

BELLMAN / HAUSMANN/ JANKE/ SCHNEIDER, 1994: Invertebrados y organismos unicelulares, Ediciones Blume, Barcelona.

Gilles Clément / Philippe Rahm. Environ(ne) ment. Catalogo Exhibition, Centre Canadien d'Architecture, Montreal, 2007

Islands + ghettos. Catálogo exposición, Heidelberger Kunstverein, 2008.

McHARG, Ian L. Design with nature, The Falcon Press, Filadelfia, 1971.

McARTHUR, Robert H. / WILSON, Edward O.: The Theory of Island Biogeography. Princeton University Press, New Jersey, 2001.

McARTHUR, Robert H. / WILSON, Edward O.: An Equilibrium Theory of Insular Zoogeography. Princeton University Press, New Jersey, 2001.

PROMINSK, M.; STOCKMAN, A.; ZELLER, S.; STIMBERG, D. VOERMANEK, H. River. Space. Design. planing strategic, Methods for Projects for Urban Rivers. Birkhäuser, Balilea, 2013.

Robert Le Ricolais. Visiones y Paradojas. Fundación Cultural COAM, Madrid, 1997.

SLOTERDIJK, Peter. Normas para el parque humano. Siruela, Madrid, 2000.

STREBLE, Heinz/ KRAUTER, Dieter, 1987: Atlas de los Microorganismos de Agua Dulce, Ediciones Omega, SA, Barcelona.

Sustainable Architecture in Japan. The Continuous Challenge 1900-2010 & Beyond Editorial Board Members of Nikken Sekkei, Tokio, 2010.

VROOM, Meto J. Lexicon of garden and landscape architecture, Birkhauser, Basilea, 2006.

Cuenca. Spain.
I. de Felipe

CHAPTER 5

BIOMIMICRY: AN INSPIRED WAY TO REGENERATIVE DESIGN IN CITIES BASED ON NATURE

Manuel Quirós
School of Architecture & Design, Instituto de Empresa University
mquiros@faculty.ie.edu

SUMMARY

The aim of this publication is to show alternatives to broaden the search for solutions that the architecture field, among many other sectors, has to achive in this century in order to make traction to the long-awaited sustainable development that humanity must design. The sustainable, regenerative and resilient strategies from nature represent excellent references for this difficult objective. Not in vain some living organisms has managed to sustain itself on Earth for the past 3,850 million years showing the best strategies and standards to adjust to the imperative laws of the planet, to function and to endure. Bacteria, plants, fungi, animals and ecosystems are today true smart engineers, architects, designers or managers that effectively show us systems, materials, processes and mechanisms that can undoubtedly help the human specie in the most ambitious and difficult challenge to which our specie has to face up to maintain the standard of life and habitability of the following generations. Biomimicry, or bio-inspired innovation, is a disruptive philosophy and methodology that is already working in the industry of many sectors but is not yet well known. This publication shows a basic introduction with three inspiring cases in architecture and how the survival strategies of the elected organisms can undoubtedly improve the current designs in sectors such as water management, energy, waste, design or into a more systemic level. These examples are real exampleas where analogies can be applied in many other cases where the potential benefits of sustainability and regeneration from the perspective of nature go beyond the mere toxicity of materials or their production or the generation of waste at the end of the life cycle of services and products. Providing new approaches of all ready published contents connecting the discipline of biomimicry with architecture, could make sense of how from cities can be reconnected with the ecosystemic services lost from the last decades with the intention to promote a shift in architecture design.

KEYWORDS

Biomimicry, design inspired by nature, sustainability, regenerative design, innovation in architecture, termite mounds, namibian beetle, systemic design.

INTRODUCTION

Humanity faces in this century several global and dramatic challenges which require high dosis of innovation that must include sustainability and regenerative approaches (WWF, 2018). Biodiversity loss, called 6th mass extinction, degradation of ecosystems including global pollution and climate chaos well shown in the exceeded planetary boundaries (Rockström et al., 2009) extended by the European Comission (Steffen et al., 2015), will require imaginative and holistic-systemic solutions which may push us "out of the box" mindset, opening the solution spaces. Humanity is being concentrated in cities and in few decades over 70% of global population will be urban based. Biophillic urbanism with several interesting actions (vegetated roofs, daylighting streams, wildlife corridors, storm buffers, parks, gardens, street canopies, green side walks and many other green and blue infrastructures ...), have been used increseanly oven the last few years with more relevance in Europe thanks to the Nature Base Solution actions to tackle environmental challenges in urban areas (European Commission, 2014) since the old continent aims to be an inspirational world leader in green solutions.

On the other hand, over the 3.85 billion years since life is registered to start on Earth evolution (Lowman, 2002), has helped to solve many challenges that living organisms and systems have running using an impresive and efficient catalogue of strategies. Nature's inventions have always inspired human challenges specially when homindis were totally connected, in a biophilic way with nature. Biomimicry can be defined as the emulation of strategies registered in the living world potentially applicable in human designs including for sure not only new material and products but also urban environments, improving social and economic systems.

The potential open solution space from nature principles (forms, patterns, strategies, mechanisms...) has catched the attention of a important set of profesionals from many disciplines (academics, industry, design, architecture, medical or economics) all over the world. Although the biomimetic field is not new, without any doubt the publication of *Biomimicry, Innovation Inspired by Nature* in 1997 from Janine Benyus (Benyus, 1997) enhanced the global attraction of this disruptive discipline. This is not the goal of the article but the reader may know the proliferation of terms used to describe the field including: biomimicry, biomimetics, bioinspiration, biologically inspired design, biologically inspired engineering, bionics, biognosis, bioreplication, biomorphosis (Hoeller et al. 2013), and even biophilic design. One fundamental difference between these valid disciplines and biomimicry is that the last is searching for sustainability and regenerative goals meliorating the actual design and manufacturing processes.

Today many experts believe that humanity, at least in the western world, have broken the connection with nature (Orr, 1994). Biomimicry can heal this broken bond using from algorithms, new potentially friendly and efficient materials to processes, structures, mechanisms, and even systems. Not in vain nature has always served as a model for mimicking and inspiration for humans to improve their life. By adapting mechanisms and functionalities from living systems now thanks to new scientific technology and holistic approach, we humans, start to understand that learning from nature is better than just learning of nature (Benyus, 1997). Biomimicry could provide a valuable vehicle for such shift in thinking because it encourages us to understand that humans are not separate from nature because we are nature and we are at the end totally dependent upon them for survival,

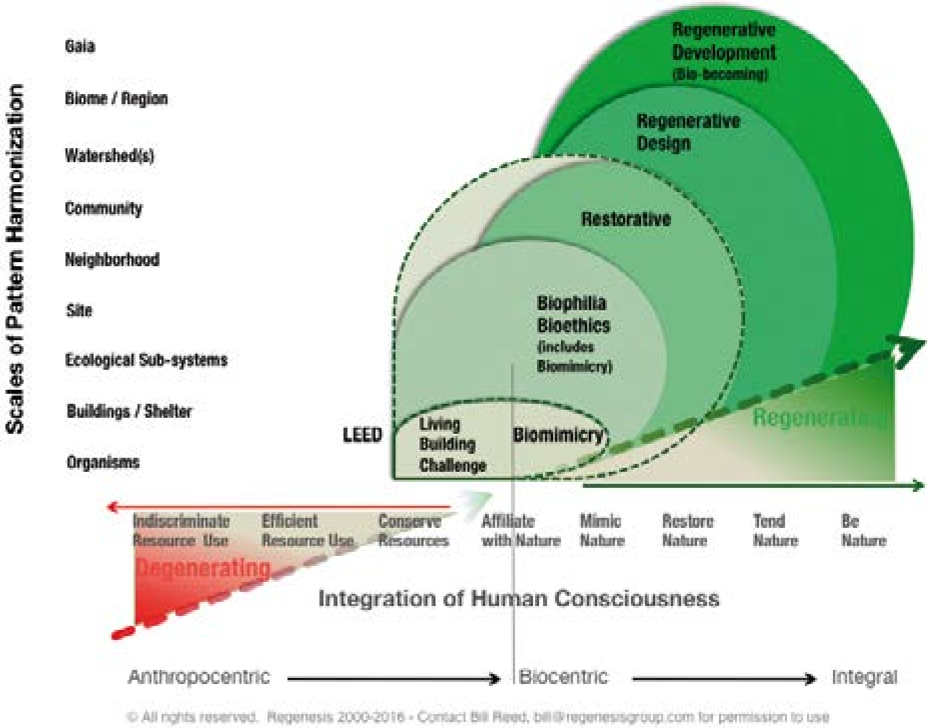


Fig 1. Scale of patterns harmonization (Bill Reed). Image used with the permission of the autor. All rights reserved©

thus the human-ecosystem relationship changes in a relevant way (Mathews, 2011).

Biomimetic architecture does not necessarily translate into a new design aesthetic and in many cases it may involves just like an interpretation, an analogy, where a particular adaptation or derivation from biology is applied (Vincent et al. 2006). This process of translation often results in designs that are not immediately aesthetically similar to the organism that inspired them, but utilise some of the same functional concepts. Biomimicry

therefore is not the same as organic, biomorphic or zoomorphic architectures, which are concerned with the visual mimicry of organic form in design. On the other hand regenerative design can be understood by designing and developing the built environment to restore the capacity of urban ecosystems to function at optimal level of health for retrofit mutual benefits of both human and non-human organisms where systemic based approach is neccesary. The potencial use of the nature´s strategies into the architecture sector opens the solution space not only related to building itself but also to a new method of manufacturing materials, structural systems, to existing problems based on biological models, as well as improved relationship of built spaces with natural environment and, in general, with living beings (Fernandez y Neila 2015). Heat, related to conduction, convection, radiation or thermal energy storage; optical, related to the transparency of the surfaces enhancing solar radiation; airflow, related to the direction and wind velocity, ventilation and air exchange, or variations in relative humidity; water systems in relation to water gain, store, regulating moisture, filtration and recycling; energy generation (Fernández & Neila, 2015) are just few fields where architecture design must improve in a deep way soon. Authors like the recognized Bill Reed affirms that intead of doing less damage to the environment, it is necessary to learn how we can participate with the environment, in something clled "living systems thinking (Figure 1) where biomimicry can play an important role.

BIOMIMICRY EXAMPLES

We are not the unique specie modifying the environment and the available resources for specific purposes (Jones et al., 1994). Beavers building dams, elephants felling trees, earth worms forming soils or mycelium fungi decomposing and recycling all types of materials and plants collecting and storing water are just few examples. Most of these living organisms procedures, contribute to habitat heterogeneity generating life supporting strategies such as resilience, stability and even food availability or shelter. In other situations species can produce a phenomenon called trophic cascade (Ripple & Beschta, 2011) where effective restoring landscape may occur with emergent properties to the ecosystems. These collaborative actions can be aligned to the common good. Human have an important source of strategies to learn from nature as organisms who also modify the environment for support. Cities occupy a relative small space in the planet, 2.7% (SEDAC) but consume an important amount of resources, producing a colosal amount of waste and GHG emissions as well as other issues. So we must look for solutions and nature can provide some good ideas to be explore and applied.

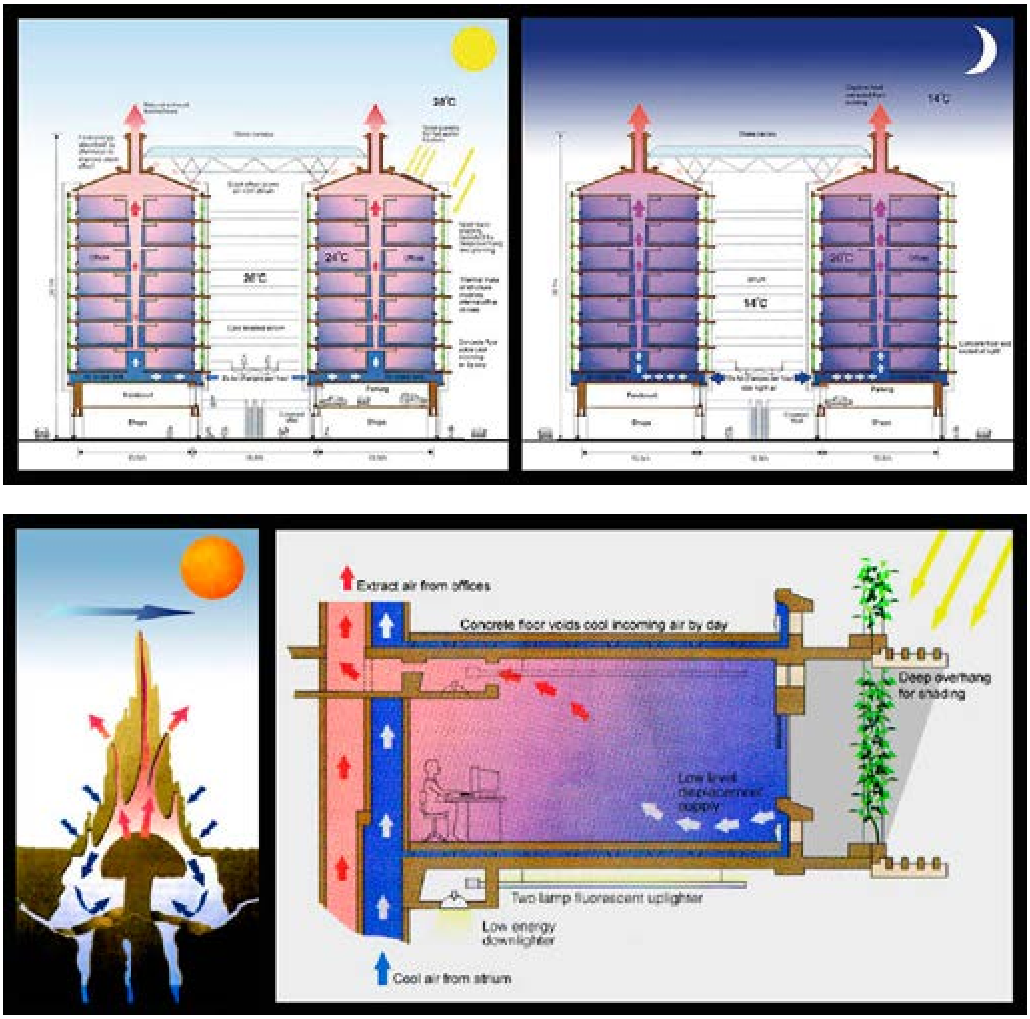
Following, I will describe just three good references in architecture as examples of biomimicry design in urban ecosytems. The first one and probably the most popular is the Eastgate Center designed by Michael Pierce in collaboration with Ove Arup & Partners engineers inspired by termites mounds; the second example based on land restoration and renewable energy plan known as The Sahara Forest Project maked posible thanks to a large public-private consortium, inspired among other living organisms in the Namibian beetle; and finally the third case, the Bullit Center, the main headquarter of the Bullitt Foundation designed by Miller Hull Partnership and inspired by how a living forest works related to the ecosystemic services they provide.

Eastgate Center

Termites standing biomass has been estimated to be higher than ungulates in savanna 100 kg Ha-1 versus 80 kg Ha^{-1}) giving some credibility to the importance of termites in the functions of these ecosystems (Deshmukh, 1989). The genus *Macrotermes*, construct large nets ($50m^2$ basal area) when basic resources like water, clay accumulation in the soil and plants for foraging (1-1,5 T/Ha/year) are available in a permanent way they consider (Boyer, 1975). This councious prevision of raw materials can be used as an analogy that we humans are not the only specie capable to make decisions in order to build shelter and other basic life supporting elements. *Macrotermes michaelseni* and *M. subhyalinus* were the two termites species that Michael Pierce studied to face a challence in Harare, Zimbaue. These between 4-15 mm minuscule insects built in terms of relative scale the tallest skycrapers which can raise up to 9 meters from the floor without considering the subterraneal galleries. Recently it have been discovered in Brazil the largest worldwide construction done by *Syntermes dirus* that has persisted for up to 4,000 years covering an estimated area of 230,000 km^2 inter-connecting tunnel networks approximately 10 km^3 of soil being deposited in 200 million conical mounds that are 2.5 m tall and approximately 9 m in diameter (Martin, S.J. et al., 2008). Like us, termites build a building-system like that suits them rather than adapting to their environment counteracting two critical physical factors: cool and humidity. To do this colosal construction the termite´s building uses zero waste using solar powered air conditioning combining the whole structure with a sustainable agriculture (fungus *Termitomyces*). These catedral-like structures made from bottom up without a preliminar instructions and without engineers and architects are perfectly nort-south oriented with a large absorbing area catching the warmth of the morning sun rays after the cold of the night. Ventilation tubes within the walls are controlled intentionally by the insects when the temperature inside rises too much in combination with tunnels below the soil which can maintain an internal temperature of 31ºC with a 1ºC variation even when outside temperaturas can vary 39ºC between day and night (Webb, R. 1994). In this colosal construcction organisms acts as a ecosystemic actor creating a resource flows that affect the composition of the current and future biophysical diversity with feedback mechanisms. This procedure is also known as ecosystem engineering (Dangerfield,1998) and can persist for long periods to the biodiversity included

You can easily imagine how termites were the primary source of bioinspiration to the architect Michael Pierce when he designed with Arup engineers the Eastgate Center in Harare, Zimbaue in 1996. This 26,000 m^2 office building and 5,600 m^2 retail space center with 450 parking use passive cooling. The cool air circulates into large floor voids containing a labyrinth precast concrete elements maximizing the heat transfer with a large surface area (Pawling, 2011). Pierce got an interior temperature maintained between 21º-25ºC range when outside are between 5º-33ºC. Works by sorting heat during the day and verting it at night when temperatures drop down using 35% of the energy required by a similar conventionally cooled building (Michael Pierce website; Figures 2 & 3). Other authors cited that this resulted reductions in energy use ranges between 17% and 52%

Looking green wall. Urcelay



Figs 2 and 3. Illustration showing the day and night function energy passive system and a comparisson analogy with air flow with a termite mound

compared to similar buildings in the area. (Turner, J.S. et al., 2008) with the evident reduction in the greenhouse gas emissions. Under this perspective, biomimicry offer another lesson to achive, a new way of collaboration with other disciplines such as biologists which together can meliorate new goals of sustainability and regeneration, something called BADT (biologists at the design table).

It seems that the current real estate market is focussed on getting all the benefits out of the users instead of creating a system that actually benefits the tenants, the maintenance and the investor. This unnatural system is not interested at all in the business sector which undoubtelly is better for us under an holistic perspective. But this things may chance at least in Europe with the new regulation coming where a drastical change in the energy demand will be demanded. The reader can go further this buiding visiting the Michael Pierce website (check the References section).

The Sahara Forest Project

By establishing a saltwater value chain, this large scale project aims for the first time a generation of electricity from concentrated solar power as well as water-efficient Seawater Greenhouses in a symbiotic combination. The potential results will produce high value crops in the desert, freshwater for irrigation or drinking, safely manage brine and harvest useful compounds from the resulting salt. Beyong these goals, biomass for energy purposes without competing with food cultivation, and the revegetation of some parts of the boundaries of the desert is also searchable. The system also wans to provide a global climate benefits by sequestering CO_2 in the facility's plants and soils formed. The project also aims to stop the alarming process of desertification through the revegetation of some specific areas. The Saltwater-cooled Greenhouses system was inspired by the Namibian fog-basking beetle, Stenocara gracilipes. By using seawater to provide evaporative cooling and humidification, the crops' water requirements will be minimized and yields optimized minimazing the water footprint (Figure 4). The desert revegetation with a collection of practices

Fig 4. Sahara Forest Project facilities illustration and evolution during the construction phase

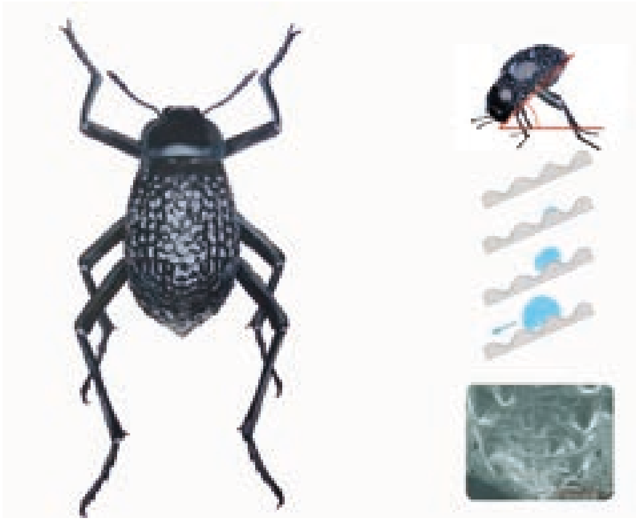


Fig 5. Namibian beetle illustration, inclined position with the hydrophobic and hydrophilic structures. (Illustrations by Luisa Nunes©). Scanning Electron Microscope images of the apex of the elytra from *Stenocara gracilipes*. Scale bar = 5 mm. (Nørgaard & Dacke, 2010). Composition made by the article´s autor

and technologies for establishing outside vegetation in arid environments thanks to the progressive enhancing humidification of the regenerative areas.

Earth is a water-based planet where this supporting life element is essential to all living organisms. Cyclic coastal current close to the deserts where fog is concentrated bringing water in the shape of minimal droplets available up to some liters in certain circumnstances can represent a predictable source of water in such arid enviroments. One of the strategies used is here is this humidity circular process in an expected fog formation. The namibian beetle moves at dawn to the top of a nearby dune where the mist flows from the seashore. The evolutive ciclical and adaptive strategy also integrates the natural property of water in the formation of drops on certain surfaces. It implies a minimum energy expenditure. The tiny drops contained in the fog are accumulated in the exosqueleton, in particular on the surface of elytra where the coleoptera contains globular nodules of about 10 µm embedded in a matrix, which combine hydrophobic (repelling) with hydrophilic (attracting) ones (Figure 5) acting as a very interesting mechanism to be applied. The combination of both properties allows the insect to drink in an extraordinary dry ecosystem. All this associated with the action of gravity, provides a simple and elegant solution (Quirós & Millard, 2011).

The Bullitt Center

The Bullitt Center Assessment Team was tasked with performing fundamental research on the ways green building and infrastructure features can produce, enhance, and transform urban ecosystem services benefits, using the Bullitt Center in Seattle, Washington, and the Living Building Challenge developed by the International Living Future Institute as key case studies (Cowan et al., 2014). The Bullitt Center is a six-story, close to 4.600 m^2 office building located in Seattle, Washington, USA. Initial requirements were stablised according to be a building net zero energy, net zero water, use non-toxic materials, provide a net increase of functional ecosystem area, enhance human health, contribute to social equity. The building serves as the headquarters for its owner, the Bullitt Foundation, while also hosting a range of innovative organizations including the International Living Future Institute and the University of Washington's Integrated Design Lab.

Regenerative Design has emerged from the 90s thanks to the work of several authors (Tillman Lyle or Bill Reed) representing an optimistic design framework suggesting that humans can help regenerate ecosystems using appropriate technologies and design strategies. Goals from the initial project were quite ambitious following these objetives from earlier ecosystem services recognized by the Millenium Ecosystem Assesment: Supporting (e.g., nutrient cycling, soil formation, and primary production); Provisioning (e.g., food, fresh water, wood fiber, and fuel); Regulating

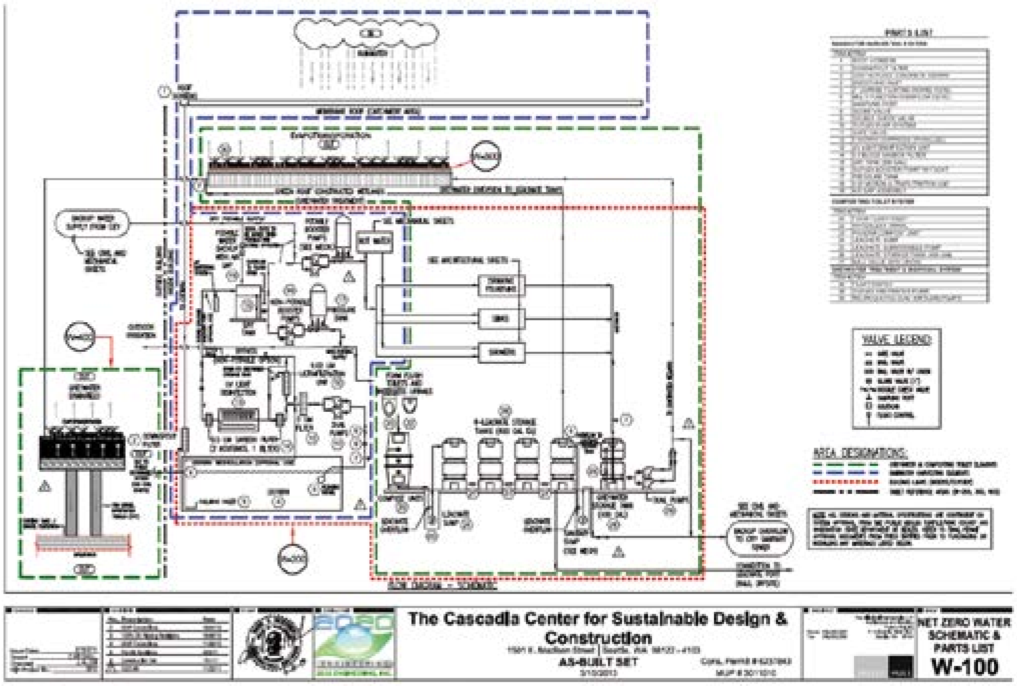


Fig 6. Net water system sheme designed to the Bullitt Center building

(e.g., climate regulation, flood and disease regulation, and water purification) and Cultural (e.g., aesthetic, spiritual, educational, and recreational). These services can be updated with more accurate suite including pollination, protecting from erosion, cycle and move nutrients, dispersion of seeds, plague control, and even non utilitarian services... (Quirós, 2018).

The building was featured as a bio-based structure where trees and forests were the inspiration under a systemic perspective. Its photovoltaic array emulates a tree canopy, capturing more energy than the building users actually uses mainly during the summer time. Connected to the city greed in the summer months when the demand is high. The net zero feature is posible because the summer production surplus must meet or exceed the winter production deficit. The electricity is measured and monitored by electricity meters providind data at any demanding. The system is reinforced with atomated blinds and operable windows maximizing daylight designing to eliminate termal bridging between the interior and exterior emulating the space between feathers and external air in birds. The building emulates a forest with a catchment from rooftop cisterns and reuse of graywater reducing thus the potable water consumption source. Then returning treated water to the soil and atmosphere (61%, published report) with ceramics (used from jellyfish to plants or fungi) and ultraviolet light with a vortex filter. According to the company report approximately 69 % of the annual rainwater runoff is collected, stored, treated, and used for potable and non-potable uses; the remaining 31% percent will be discharged as stormwater, ensuring the integrity of downstream hydrology to the Lake Union. Historically, in an old-growth forested, approximately 39% of the rainfall ran off the surrounded soil (Raich, 2017) so surprisely results obtained seem to be similar. Beyond and following the rule in nature that waste equal resource, all waste from waterless toilets in the building is composted with a long aerobic process of decomposition in large facilities where after stabilized is taken and released in a bird sancturary as well as making biosolids as fertilizers (Figure 6). This procedure is based in natural ecological systems.

Finally the mayority of the material used were identified and not included in the Material Red List in the Living Building Challenge (although the The Bullitt Center team does not warranty these products in any way according to the information from the website). The list include local wood (Forest Stewardship Council, FSC), concrete, steel, glass locally sourced with recycled content. FSC's mission is to promote environmentally appropriate, socially beneficial, and economically viable management of the world's forests, and the organization holds the restoration and protection of ecosystem services as one of its top priorities. This certification also is very restricted with the use of hazardous pesticides, herbicides and even atrzine a well known endocrine disruptor. Some of the non used materials are asbestos, cadmium, CFCs, lead, PVC, Wood treatments containing creosote, arsenic or pentachlorophenol just to describe some frequently used in most of edifications. A final remarkable featured from the buiding construction is that it will be dissasembled in

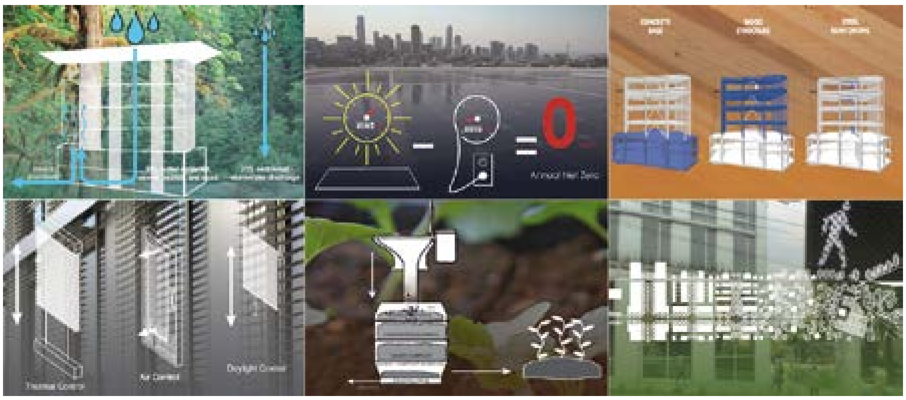


Fig 7. Some of the features bioinspired from the Bullit Center (images courtesy from the Bullit Center website. Composition by the article´s autor)

Fig 8. The Bullitt Center Building. General edification view (photo by John Stamets); wood pillars structure during the construction; hydronic heater controller and composters (photos by Brad Kahn). |Source: flickr/bullitt_center | Creative commons CC BY-NC 2.0)

200 years, so it is designed from the bottom up releasing the potential materials to be reused in a second life instead of being converted in demolition waste (Cowan et al., 2014).

SUSTAINABILITY AND REGENERATION FROM THE NATURE´S PERSPECTIVE

How can we build more efficient structures using non toxic materials in architecture?; how can we produce zero waste?; how will manange water treatment and natural catchments?; how energy can be produced, storage and distributed from a city?; how can buildings be collaborative with the surroundings city structures?... We will reach sustainability when we will be able to take back the ecosistemic services from cities. Nature has solved most of the questions above and many much more and without doubts can advice from a systemic perspective very interesting strategies. They are summarized under several different terminology (Life´s Principles, Nature Unifying Patters, Nature Inspired Design...) according to the institutions (Biomimicry 3.8, Biomimicry Institute, Delft University,...) but at the end, all of them explain how Life works. We can use the following chart designed by Biomimicry 3.8 (Figure 9) where most of the principles and subprinciples can be used in the architecture sector. Although in the diagram you see separated groups, all principles are interconnected containing subprinciples for a better applicability. This particular aspect requires training for a better understanding and it is out of the scope of this publication. Remember that the diagram represents the strategies of closet o 30 million species evolved over 3.8 billion years. The outer titles/caption represents the Earth´s operating conditions and the center of the chart is like a mantra which biomimicry practicioners use to check if the proposal follow the life´s principles, celebrating life.

Read them carefully and try to imagine your design choices if can be aligned with the principle selected. You may invest time looking for understanding the principle with other examples or definition. At the end of this new learning process you may change our basic assumptions to evolve into this paradigm shift.

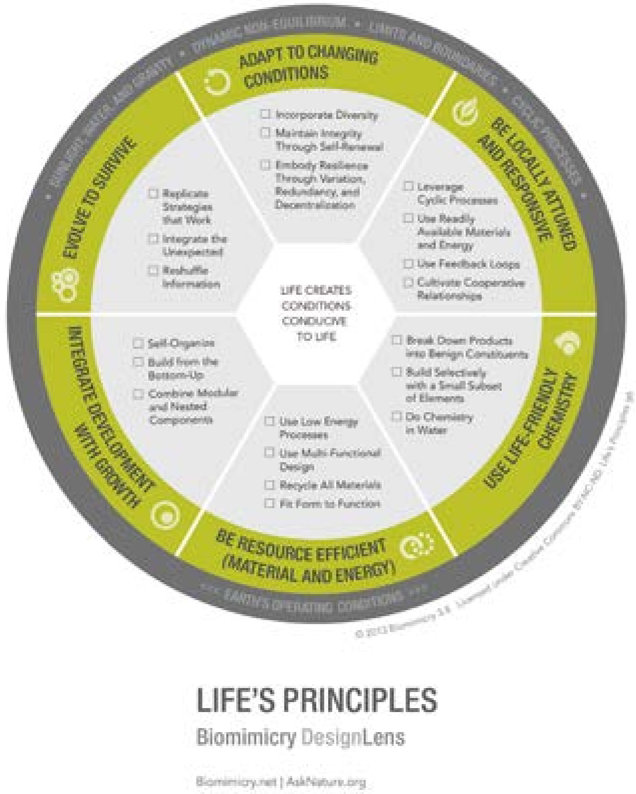


Fig 9. Life Principles chart designed by Biomimicry Institute summarizing Nature´s strategies supporting sustainability and regeneration fit in. 2013 © Biomimicry 3.8. Licensed under Creative Comons BY-NC-ND

Architectural product manufacturers as well as architects as well have the opportunity to embrance this disruptive way of thinking and acting. Living organisms and systems thanks to the refinement of evolution teach us the way to fit in reaching an efficiency level dificult to believe but realistically viable. The matter is tos peed up this transformation no matter our personal constrains. Stimulating innovation and fixing the belief that we humans are surronded by genious to explore, we can conclude that the future is waiting for an amazing design solutions which point us to optimism.

REFERENCES

BENYUS, J. M. (1997). Biomimicry: Innovation Inspired By Nature (1st ed.). New York, NY: William Morrow.

BOYER, P. (1975). Actions de certains termites constructeurs sur révolution des sols tropicaux. Annales des Sciences Naturelles Zoologie (Paris) Série 12. 17:447-504

COWAN, S., DAVIES, B., DIAZ, D., ENELOW, N., HALSEY, K. & LANGSTAFF, K. (2014). Optimizing urgan ecosystems Services: The Bullit Center. Portland, OR: Ecotrust & The Bullit Foundation.

DANGERFIELD, J.M., MCCARTHY, T. S., ELLERY, W. N. (1998). The Mound-Building Termite Macrotermes michaelseni as an ecosystem engineer source. Journal of Tropical Ecology, Vol. 14, No. 4 507-520.Cambridge University Press.Permanent link: [http://www.jstor.org/stable/2559880]

DIRECTORATE GENERAL FOR RESEARCH & INNOVATION, CLIMATE ACTION, ENVIRONMENTA, RESOURCE EFFICIENCY AND RAW MATERIALS (2015). Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities. Final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities. ISBN 978-92-79-46051-7

FERNÁNDEZ CADENAS, M., NEILA GONZÁLEZ, F.J. (2015). Biomimicry in climate adaptive building skins: relevance of applying principles and strategies. VII International Congress on Architectural Envelopes. San Sebastian-Donostia, Spain.

HOELLER N. et al. (2013): "Developing a Common Ground for Learning from Nature" Zygote Quarterly Journal, issue 7, pages 134-145. ISSN 1927-8314 [http://issuu.com/eggermont/docs/zq_issue_07_final/134]

LAWTON, J.H., JONES, C.G. & SHACHACK, M. (1994). Organisms as ecosytems engineers. Oikos 69:373-386.

LOWMAN P. (2002): Long Way East of Eden: Could God Explain the Mess We're In?. Paternoster Press, Milton Keynes, UK, pp. 1–390. ISBN: 1842271083

MARTIN, S.J., FUNCH, R.R., HANSON, P.R. & YOO, E-H. (2018). A vast 4,000 year old spatial pattern of termite mounds. Current Biology Magazine, 28. Nov 19. Permanent link: [https://www.cell.com/action/showPdf?pii=S0960-9822%2818%2931287-9]

MATHEWS, F. (2011). Towards a deeper philosophy of biomimicry. Organization & Environment, 24, 364–387.

NØRGAARD, T. & DACKE. M. (2010). Fog-basking behaviour and water collection efficiency in Namib Desert Darkling beetles. Frontiers in Zoology 7:23

ORR, D. W. (1994). Earth in mind. On education, environment and the human prospect. Island Press.

PAWLING, M. (2001). Biomimicry in Architecture. RIBA publishing, London130 pp.

PIERCE. M. [http://www.mickpearce.com/Eastgate.html]

RAICH, J.W. (2017). Temporal variability of soil respiration in experimental tree plantations in lowland Costa Rica. Forests 8(2). 40.

REED, B. [https://regenesisgroup.com/]

RIPPLE, W.J. & BESCHTA, R.L. (2001). Trophic cascades in Yellowstone: The first 15 years after

Wolf reintroduction. Biological Conservation: Vol. 145, issue 1, jan 2012, 205-213. [https://doi.org/10.1016/j.biocon.2011.11.005].

ROCKSTROM, J., W. STEFFEN, K. NOONE, A. PERSSON, F. S. CHAPIN, III, E. LAMBIN, T. M. LENTON, M. SCHEFFER, C. FOLKE, H. SCHELLNHUBER, B.NYKVIST, C. A. DE WIT, T. HUGHES, S. VAN DER LEEUW, H. RODHE, S. SORLIN, P. K. SNYDER, R. COSTANZA, U. SVEDIN, M. FALKENMARK, L.KARLBERG, R. W. CORELL, V. J. FABRY, J. HANSEN, B. WALKER, D. LIVERMAN, K. RICHARDSON, P. CRUTZEN, & J. FOLEY. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2): 1-32

SEDAC. Gridded populationof the World (GPW), v4. Socioeconomic Data and Application Center (SEDAC) a Data Center in NASA´s Earth Observing System Data & Information System (EODIS). [http://sedac.ciesin.columbia.edu/data/collection/gpw-v4]

QUIRÓS, M. (2018). Biomimesis innovación sostenible y regenerativa, inspirada en la naturaleza. CONAMA 2018. [http://www.conama.org/conama/download/files/conama2018/STs%202018/5234_ppt_MQuir%F3s-Gald%F3n.pdf].

QUIROS, M. & MILLARD, T. (2011). Biomimesis o como la naturaleza diseña productos y servicios sostenibles. Congreso Nacional de Medioambiente. CONAMA Madrid 2011.

TILLMAN LYLE, J. (1994). Regenerative Design for Sustainable Development. New York: John Wiley & Sons.

TURNER, J.S. & R.C. SOAR. (2008). Beyond biomimicry: What termites can tell us about realizing the living building. First International Conference on Industrialized, Intelligent Construction (I3CON). 2008: Leicestershire, United Kingdom.

STEFFEN, W., RICHARDSON, K., ROCKSTRÖM, J., CORNELL, S.E., FETZER, I., BENNETT, E.M., BIGGS, R., CARPENTER, S.R., DE VRIES, W., DE WIT, C.A., FOLKE, C., GERTEN, D., HEINKE, J., MACE, G.M., PERSSON, L.M., RAMANATHAN, V., REYERS, B., & SÖRLIN, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science 347(6223). DOI:10.1126/science.1259 855.

VINCENT, J.F.V., BOGATYREVA, O. A., BOGATYREV, N. R., BOWYER, A. & PAHL, A.-K. (2006): Biomimetics. Its practice and theory. Journal of the Royal Society Interface, 3, 471–482.

WEBB, R. (1994). Offices that breathe naturally. New Scientist 11, june. [https://www.newscientist.com/article/mg14219294-200/]

WWF. (2018). Living Planet Report - 2018: Aiming Higher. Grooten, M. and Almond, R.E.A.(Eds). WWF, Gland, Switzerland.

Tokio. Ark Hills.
I. de Felipe

CHAPTER 6

LIVING WALL SYSTEMS: TECHNOLOGICAL AND ENVIRONMENTAL OPTIMIZATION STRATEGIES

Valentina Oquendo-Di Cosola
PhD Student in the Department of Construction
and Technology in Architecture at Universidad Politécnica de Madrid

Francesca Olivieri
Professor in the Department of Construction and Technology
in Architecture at Universidad Politécnica de Madrid

INTRODUCTION

Not long ago the cities were made up of large rural areas and an economy based on agriculture and local production, it has been after the industrial revolution that the development of urban transformation came about, from two main points of view: the demographic and the constructive, by the effect of the exodus produced. Consequently, the increase of the population in the cities has reached unexpected levels generating in time the massive construction of buildings and paving.

Even though contradictory but true, cities have a greater number of square meters available in the vertical surfaces of buildings that can be tapped, in comparison with the surface available in the territory of cities. The percentage of built-up land in cities is equivalent to surfaces destined for the absorption and irradiation of heat, a condition that leads to high energy consumption for the conditioning of spaces. Today urban areas are recognized as the largest producers of pollutants, as a result of human activities (Diamond and Hodge, 2007). Research into sustainability and innovation in cities has led architects, engineers and professionals from other disciplines to rethink the city model and replace the "consumer" model in which the building is a device that consumes energy, water, and raw materials, through a mechanism that leaves aside natural resources such as the sun, wind, rain, and soil. The new paradigm establishes environmental awareness, demanding a renewed relationship between architecture and nature, in which the building makes use of natural resources.

Greening the building envelope allows obtaining some benefits relating to the improvement of its efficiency, and its ecological and environmental performance, as well as an increase in the biodiversity (Perini et al., 2011). Living Wall Systems (LWS) as part of vertical greening solutions are a result of the interest in restoring the environmental integrity of urban areas, what can be defined as sustainable architecture or eco-architecture. These concepts are connected to global environmental problems and to the strategies to reduce environmental impacts due to the CO_2 building emissions and other greenhouse gases (Dunnett, N., Kingsbury, 2008). The integration of vegetation on buildings through green facades offer the potential to learn from traditional architecture; change its aesthetics (Ottelé et al., 2011); the improvement of air quality and reduction of air pollution (Klingberg et al., 2017; Gourdji, 2018), related to the reduction of fine dust levels (Perini et al., 2017); increase of biodiversity (Perini et al., 2011); the reduction of heat island effect in urban areas (Sheweka and Magdy, 2011; Mariani et al., 2016), and the reduction of energy consumptions for cooling and heating (Perini and Rosasco, 2013; Pan and Chu, 2016).

There are some aspects that influence for both insulation and cooling benefits: the thickness of the foliage, the water content, the air cavity between different layers and the material properties (BRE Global, 2014). LWS are the result of greening surfaces with plants, rooted into the ground, in the wall material or in modular panels attached to the façade, and can be classified into green façade and living wall systems according to the growing method (Perini et al., 2011).

The new ways of greening vertical surfaces on buildings offer new possibilities from the sustainable construction point of view, especially in energy savings. Green facades green walls act as a passive system through

Fig 1. Sportplaza Mercator – Amsterdan. VenhoevenCS

four mechanisms: the shadow produced by the vegetation, the insulation provided by vegetation and substrate, the evaporative cooling through evapotranspiration, and finally the barrier effect to the wind (Pérez et al., 2011). The insulation of a building provides energy savings for both heating and cooling. The R-value of insulation material is a measure of its resistance to transfer of heat. Establishing the R-value offered by a LWS depends on a complex interaction of all the materials used, the depth of the growing substrate and the amount of water held in the substrate, as well as the plant selection, degree of coverage by plants and whether that coverage is present (Culnane et al., 2014).

The climatic conditions such as solar radiation also may result in different outcomes on surfaces cooling efficiency. Vegetation can dramatically reduce the maximum temperature of a building by shading walls from the sun, with daily temperature fluctuation by as much as 50% (Dunnett, N., Kingsbury, 2008). Especially during the summer months, LWS has the dual effect of reducing solar energy entering the interior through shade and reducing heat flow into the building through evaporative cooling, resulting in energy savings.

TECHNOLOGY AND PERFORMANCE

Over the last few decades, uncontrolled urbanization has ignored the benefits of sustainable development, and the results today are visible to all: excessive noise, pollution, and congestion in cities. Sustainability as a whole considers a series of interconnected elements such as the reduction of the use of energy from fossil fuels; the reduction of water consumption; the reduction and management of urban waste; the improvement of air quality; and the use of environmentally friendly materials (Sheweka and Mohamed, 2012). The urban space, including the vegetation used in roofs and facades, is just a piece of the puzzle.

Plant façade systems comprise a wide range of technical and design solutions with different characteristics; in today's market, it is possible to find numerous products, many of which are linked to a patent or industrial property. They are known as technologies for green walls, consisting of vertical supporting structures, which may or may not be attached to the façade of a building. Depending on the level of complexity, there are different types ranging from very simple configurations to very complex stratigraphy and high technology. The first patent for a vegetal façade system was made by Stanley Hart White, followed by Patrick Blanc, who is considered the inventor of living wall systems (Tatano, 2008).

As far as the systems are concerned, the most important characteristics derive from the components and materials used. Living walls are generally more complex than other technologies, even though they may vary according to the type, in the practice the dimensional and material characteristics of the components are similar, given that the functions required are always the same. However, there are a series of technological components of these systems that make possible the whole functioning of a vegetal facade, which consist of requirements and functional needs.

A living wall system is composed of some constant or invariable elements, and some variables according to the exigency of the project. Based on this classification they can be defined as primary elements and secondary elements (Bit, 2010).

Primary elements:

- **Supporting element**
  It is one of the main components of any system, a certain level of rigidity is necessary to guarantee stability from a structural point of view. Mechanical resistance is another fundamental aspect, the supporting element must be able to resist the mechanical effort exerted by the growth of the roots of the plants,

and the increase in weight of the substrate when it is saturated. This element can be elaborated in different materials: aluminum, recycled plastic, felts, steel, among others.

• Water absorption and retention element

The objective of this element is the impermeabilization of the system to water or other liquids, the function, therefore, is to prevent the passage of liquids between the internal layers of the system, and between those external that come into contact with the building. It is usually the last layer of the system. The materials used for this layer can be bituminous membranes, PVC membranes, felts, etc.

• Substrate

The substrate can be organically made up of materials such as vegetable fibers, humus, clay, perlite, felts, etc., or hydroponic, made up of mineral salts such as potassium, calcium, magnesium, and nitrogen. The mixture obtained from these materials must be suitable for the type of plants selected, must have a contained weight and an adequate water retention capacity, as well as being compatible with the climatic context. The objective is to control the agronomic capacities of the system; the water and nutritional needs of the entire system will be established on the basis of the type of substrate.

• Vegetation

The vegetation represents the most important element of the system, but also the one that requires the most attention. An optimal system cannot leave aside the agronomic requirements that will allow the maintenance of plant species. If these requirements are not met, this will lead to the need for extraordinary maintenance and, consequently, to an increase in costs. The selection of species is made on the basis of the cycle of seasons, water requirements, solar exposure of the facade, the climatic context, among others.

• Irrigation and fertilization system

A correct supply of water and nutrients is necessary to ensure plant density and expected bioclimatic functions. The system can be manual or automated. The frequency of irrigation is established according to the type of plant species, type of substrate and seasons.

a) *b)*

Fig 2. (a) Felt system with substrate in pockets (b) Pre-cultivation of species for plant façade system

It is usually composed of:

Secondary elements:

- **Vapor barrier layer**
- **Insulating layer**
- **Vapor pressure diffusion layer**
- **Separation layer of materials of different origin**

COST AND MAINTENANCE

Maintenance

In a living wall system, the subsystems to which special attention must be given are the vegetation, the substrate, the support system, and the irrigation and fertilization system. The activities to be carried out in the management of a plant system integrated into a building are divided into obligatory, i.e. they respond to ordinary maintenance, while others may be eventual or extraordinary.

The frequency of ordinary maintenance will be higher during the first years, mainly due to the natural biological development of the plants. Therefore, it is necessary to control from the nutrition of the plants up to the behavior of the bearing structure before the growth of the roots. Other criteria to consider within the maintenance are: the selection of species and the dimensions of the system, what will indicate the average of the frequency of the maintenance, greater is the dimension of the system and greater will be the costs of maintenance.

It is important to point out that the management and maintenance of these systems require a temporary frequency, so it is necessary in some cases to have common access to maintenance plans. In most cases, there is no knowledge of the maintenance required, as it is normally carried out by the companies producing the systems, or other gardening and maintenance companies, which in some way make this type of technology more expensive.

Costs

The realization of a vegetal façade system includes costs related to installation and maintenance. As systems are integrated into existing building envelopes, it is important to evaluate all the possible costs resulting from the maintenance of the vegetation and all the technological layers of the system. This makes it possible to differentiate between two types of costs: *installation-related* costs and *maintenance*.

It is almost impossible to estimate the average cost of a plant façade system since there are many variants that influence it. It is therefore very important to know the technical requirements of these systems and the materials are used to evaluate the project options. It is also necessary to highlight the reduced access to information on the construction, maintenance and professional management of living wall systems, as well as the opportunity to develop manuals or guides to guide designers and users.

CONSTRUCTIVE CLASSIFICATION OF THE SYSTEMS

The integration of vegetation into architectural projects has led to the development of plant wall systems in the market. These can be classified on the base of the constructive system (Olivieri, 2013), nowadays most of them can be divided into:

Continuous vegetal facades:

- **Without support:**
  Systems that are an integral part of the enclosure, constituting the same support structure for the development of vegetation.

- **With vertical support:**
  Systems formed by vertical structures (cables, meshes, etc.) that constitute the structure in which the vegetation grows.

- **With horizontal support:**
Systems made up of planters or containers added to the finish of the building, which at the same time form a continuous and independent structure.

- **With vertical and horizontal support:**
Systems that constitute the union of the two systems previously described. In this type of façade, the plants grow in flower boxes and develop vertically due to the support structures.

- **Adhered to the wall:**
Systems realized by means of structures of support covered with a layer of synthetic felt in which the plants take root.

Modular vegetal facades:

- **Panels**
A system of industrialized and pre-cultivated panels, of variable dimensions, that allow covering vertical surfaces at small and large scales.

- **Blocks**
Industrialized and pre-cultivated panel system, which allows covering vertical surfaces at small and large scales. The modularity allows the substitution of plants in case of damage. They have low permeability and therefore tend to have complex stratigraphy, which translates into greater weight.

- **Gabions**
A system developed based on the creation of panels with gabions, using a metallic mesh, stone and substrate, adding in some cases concrete to rigidize the system. It is also a constructive element; however, the opacity and permeability limit its use.

OPTIMIZATION STRATEGIES

Within the existing systems in the market, the system of modular plant facades in panels has been the most developed in the current market. On which, this publication will be based to propose the optimization of a living

Fig 3. Metro Station, Lausanne, Switzerland. Bernard Tschumi Architects

Fig 4. Green Cast, Japan. Kengo Kuma Associates

Fig 5. Límmeuble qui pousse, France. Edouard Francois

wall system taking into consideration three phases within its life cycle:

- ***Production***: the design phase in which the components and materials of the module are selected.

- ***Construction:*** the selection of technological solutions that contribute to the development of a technological and environmentally responsible module.

- ***Maintenance:*** phase in which the element must maintain its initial characteristics for as long as possible, reducing its emissions and energy consumption.

From the analysis of the systems and the study of the international scientific literature (Serra and Politecnico, 2009; Perini et al., 2011; Sheweka and Mohamed, 2012; Chel and Kaushik, 2013; Giordano, Montacchini and Tedesco, 2013, 2016; Tamási and Dobszay, 2015; Pérez-Urrestarazu et al., 2016; Tedesco, Giordano and Montacchini, 2016; Xing, Jones and Donnison, 2017b) it was possible to identify some good practices and reference strategies. These strategies have been translated into optimization requirements, and through the application and verification of these requirements on the systems, it has been possible to obtain results of systems optimizations.

1. Production

- Functional prototype: an excellent prototype of LWS must be functional and have a design that allows offering the appropriate conditions to the selected project.

- Facilitate flexibility and adaptability to different environments
The system must have flexibility and adaptability features in a way that can be disassembled and assembled without having to make substantial modifications. The purpose is to be able to disassemble it into parts and transport it if necessary. This allows saving in the use of materials, time and raw materials.

- Provide maintenance guidelines
To give illustrative guides of the system as detailed as possible in terms of assembly, maintenance, dismissal and separation of the components of the system. In this way, the owner of the installation will be able to monitor his own system and solve general problems that are normally solved by companies.

- Minimize component thicknesses
Considering the entire thickness of the system, it is important to point out that the final dimensions of the module should not exceed the dimensions of a standard enclosure. The reduction of thicknesses allows saving on the use of building materials.

- Use of materials with low environmental impact
The aim is to reduce the use of energy from combustion. Embodied Energy (EE) is the primary energy needed for the extraction of raw materials, for material processing mechanisms, for transport and on-site installation. The use of materials with low incorporated energy content maximizes the level of sustainability. Even when certain materials have high levels of embodied energy, most of that energy can come from renewable energy sources.

- Use materials with high environmental performance
The use of materials that, through a process of recovery and transformation, are again useful and readmitted to the market, with another function or the same one. This drastically reduces the embodied energy of the new material. This type of material is called secondary raw material. The objective is to maximize the use of materials derived from waste transformation activities, taking into account their technological and environmental performance.

• Module dimensions: the module must consider the costs of maintenance and construction, influenced by the dimensions, the design, installation flexibility, and the materials used.

- Reduction in the number of materials
Reduce the parts that comprise the technical element, excluding the anchors, and considering the irrigation system and the support frame of the system as elements that can be simplified. By reducing the parts of the system, the costs that can be derived from the assembly of a greater number of parts are reduced, as well as extending manufacturing times.

- Use integrated fuction elements
The use of elements that perform two or more functions within the system allows to limit the number of elements used, and indirectly reduces the thickness of the finished module. For example, a substrate that in addition to supporting the plants, performs part of the structural function of the panel, giving it rigidity. In other words, obtain the same result with fewer elements.

- Reduce costs associated with the assembly and acquisition of materials and components
In most cases living wall systems are made with a complex stratigraphy, which contemplates a high number of materials, elements, and components, with a direct influence on costs and environmental impact in the different phases of the life cycle. The purpose of this case is to reduce costs through the reduction of the number of materials and the standardization of the components.

- Reducing the need for irrigation
The use of substrates that may hold long-term nutrient solutions, and plants that have low water needs. This makes it possible to reduce consumption related to fertilization and irrigation, thereby reducing costs during the use and maintenance phase. This will vary based on the technology employed and the type of project.

• Substrate selection: the substrate must provide a support structure to the plants, and allow access to water, air, and nutrients, in order to decrease maintenance.

- Reduce substrate thickness
Minimizing the thickness of the substrate allows having under the control of the thickness of the whole module, reducing also the use of primary and secondary raw materials. This leads to advantages for the transport and handling of the modules.

- Use secondary and recycling raw materials
Proper selection of substrate type and volume is necessary to obtain benefits of temperature reduction, sound absorption, and improved air quality. The use of recycled and organic materials in the substrate mix reduces embodied energy and consumption of materials from non-renewable sources. An example could be the use of recycled plastic from recycled rubbers as a drainage layer in modular roofing solutions to replace porous materials such as pozzolans or expanded clay.

• Selection of the fertigation system: the selection of the appropriate plant and the depth of the substrate must be among the considerations to maximize the potential.

- Maximize the use of integrated devices for irrigation and energy needs
Verifying if the solutions used are integrated with the irrigation and lighting system allows obtaining important advantages, such as: having preventive control of the aesthetics of the garden, defining maintenance procedures and avoiding improvised solutions. The standardization and integration of these two systems allow to extend the useful life of the system.

• Selection of plant species: selection must be carried out according to the scale of the project and the climatic conditions.

- Select plant species with shallow roots
The species with superficial roots guarantees the containment of the thickness of the substrate and consequently the total thickness of the module.

- Select evergreen plant species
The aesthetic aspect of a living wall system is among the main requirements, this selection is important especially in the management of the aesthetics of gardens during the various seasons of the year. The objective is to avoid management problems since in other cases it is necessary to eliminate dry and fallen leaves during the autumn and replace them more times during the year.

- Select non-allergenic plant species
Pollen is invisible particles produced by plants for reproductive purposes, which diffuse into the air and for certain individuals are a source of allergies, especially in spring. The use of species that do not produce flowers can be a solution.

- Select plant species capable of improving air quality
Many plants have the ability to fix pollutants present in the air, such as gases, suspended particles and Volatile Organic Compounds (VOCs). There are species that are particularly effective in this task, making it a tool for improving air quality.

- Select plant species capable of improving aesthetic quality
Varying the plant species makes it possible to create different environments and improve the aesthetic effect produced by vertical gardens. Selecting species characterized by seasonal changes in color makes the visual effect change continuously, as well as providing dynamism in a façade.

2. Construction

• Drainage of the system: to improve the drainage of the LWS system, they can be made in a concave shape, inclined, perforated or made of a porous or absorbent material.

• Rainwater collection: the irrigation system should consider rainwater collection and recycling of irrigation water to minimize the use of drinking water. The recovery of rainwater, as well as the fertilizer solution, is essential from an economic and energy point of view. Using recovery systems saves water and other resources. One possibility could be the use of a water collection sump together with a solution recirculation pump.

• Structural decay: the structural decay of the substrate must be avoided; therefore, the installation, fertilizers, and nutrients must be provided in a precise way. The living wall systems are realized with a stratigraphy constituted by an external stratum that contains the plants and the substrate, a supporting structure, a hydrophilic layer, a layer of drainage and development of the roots and finally the closing layer. The objective is to guarantee in each system the presence of an external layer that avoids the structural decay of the substrate.

• Waterproofing: due to the presence of substrate, humid environments are created, an excellent system must consider a waterproofing insulation layer or an air chamber.

• Ergonomic: the system and the arrangement of the fertigation system must allow the easy hooking and unhooking of the system due to substitutions or other problems.

• Structural safety: the weight of the system must be considered in such a way as to avoid overloading the load-bearing structure. The module must be stable under the effect of its same weight, this is fundamental since it simplifies the storage, transport, on-site installation, and maintenance. The purpose is to verify during the useful life which is what can compromise the vertical support structure and reduce the total weight of the element.

3. Maintenance

● Maintenance of the system: maintenance must be programmed according to the objectives set out in terms of lifetime and available resources.

- Limit pruning
The maintenance of these systems requires pruning, the frequency depends on the species and the type of substrate. Some species do not need pruning, they grow to a point and keep it for the rest of their life, others grow to form rugs or in height, and this in some way limits pruning. The goal is to reduce pruning by selecting the right slow-growing species and reducing maintenance costs.

- Reduce the need for energy supply from non-renewable sources
It is an important strategy for the design of a sustainable solution. This will be possible based on the efficiency of the pump that distributes the solution, of the irrigation controllers, and of the lamps used in some cases for the illumination of the gardens in substitution of the solar light. The aim, in this case, is to connect the fertilization, irrigation and lighting systems to others that use energy from renewable sources.

● Flexibility: the systems must be individual containers that can allow pruning and substitution according to the system. A simple hooking and unhooking system are essential.

- Maximize the use of easily assembled components
From the verification of the systems of anchorage of the modules, that can be simplified from their physical characteristics. The parameters that can be optimized in this field are related to the disposed of the system anchoring so that it can be installed by a single person.

- Facilitate the substitution of materials
Facilitate the process of assembling and disassembling of the parts of the system, having studied the operations to be carried out. This allows an optimization of the use of materials, helping to identify the elements that no longer fulfill their function and that must be replaced.

● Dismissal: at the end of the useful life of the system, the total removal of the system to the landfill should be considered, where the costs include the removal of the plants, the support system, and the irrigation system.

- Maximize the use of reused/reusable materials and components
Increasing the percentage of materials that can be reused in their final state leads to savings in energy terms, since recycling - as it may be preferable to disposal in landfills - implies an energy cost. The aim is, therefore, to save resources and energy by reusing certain raw materials.

- Maximize the use of materials and components upcycling/downcycling
Upcycling is an activity where used materials are converted to new ones, or in other words, new objects are created without having to face the costs of disposing of the material. On the other hand, downcycling implies that in the material transformation phase there is a loss of value in its characteristics, so it is not possible to obtain products with the same performance. The purpose, in this case, is to ensure that the system can be built from upcycling materials or downcycling derivatives.

- Prioritize the use of materials that are non-toxic or harmful to health
In order to reduce environmental impact, it is important to identify toxic materials within the system, disassembly and priority separation of these, as they can be harmful to health if improperly disposed of. This avoids the emission of toxic gases into the environment and prevents recyclable or reusable materials from being wasted, which is the same as saving energy and materials.

- Select incinerable or combustion materials
The incineration and combustion of materials is the last opportunity for certain materials to have a function within their life cycle. The production of heat from combustion is used for electrical production and heating. The objective in this case, although it is not the most sustainable scenario, is to select and calculate the percentage of materials that can be incinerated or combusted at the end of their useful life for use as thermal and electrical energy.

- Use products with similar lifecycle
Ensuring that the useful life of system components is similar and avoiding having to intervene frequently in different parts of the system. The aim is to ensure that the components of the modules have homogeneous durability, which implies knowing the life cycle of each material used.

OPTIMIZATION OF A LIVING WALL SYSTEM

The optimization proposal was made upon the basis of 5 alternatives with concrete actions. Based on this proposal, the weaknesses and strengths of the systems are highlighted, from which a selection is made. These alternatives summarize in some way the parameters to be optimized, in some cases, one strategy can contribute to more than one requirement. Since many possibilities open up, the aim was to integrate the current efficient features of the systems, with those that can be improved.

1. Do it youself (DIY) guides:

The guide is proposed as a strategy that responds to the requirements related to a functional prototype, for the plant species selection and dismission of the systems, which response to the production and maintenance phase. Projecting a guide or manual to provide simple information and step-by-step instructions on how to plan or implement specific actions, it is about offering a free tool to the consumer.

Creating a guide or manual includes:

- Create qualified consumers, good users who will provide the intended use and maintenance based on their economic and physical availability;

- Do not involve more participants in the production or maintenance of the product, which implies a reduction of the investments;

- Offer a product that contributes to the psychological well-being of people;

- Stimulating social activity and the exchange of knowledge, starting with providing a product with a guide for construction and maintenance.

a. Maintenance guide:

After the installation of a façade, one initiative to reduce associated costs is to develop maintenance guidelines. In which the functioning and technical characteristics of the irrigation and fertilization system can be explained, as well as the type of species and substratum and their requirements.

To structure a maintenance guide, it is necessary to take into account:

- *Maintenance objectives*, to create a base-line with the objectives to be achieved, taking into account climatic conditions and selected plant species.

- *Times of the system*, the times when the maximum density of vegetable species is reached.

- *Technical instructions* related to the management of the irrigation system in case of damage or breakage.

- *Suggested cyclic maintenance programs*, in order to offer a guide for future problems or interruptions.

Building a vertical garden

- *A toolkit*, a guide to possible tools needed to repair possible damage.

- *Instructions of fertilizers*, for replacement, if necessary.

- *Technical data sheets of plant species*, with their specific requirements, useful in the case of replacements.

Some projects, in particular, those on a large scale, require maintenance by third parties; in other cases, some private projects require maintenance contracts for a period not inferior to one year, to ensure optimal operation. These tasks require an extra expense in the installation of this type of systems. A DIY system, with all its components purchased separately, can cost around 170€/m^2, plus approximately 150€/m^2 for the substrate, the plants, the irrigation system, and fertilization. While a professional system can be between 1100 and 2800€/m^2, including 12 months of technical assistance. This means that the proposal of a maintenance manual or guide would be one of the most economical options to reduce the cost of these systems. (Culnane et al., 2014).

A maintenance guide for a living wall system could be structured on the basis of the following activities:

- Maintain the design: replacement or replanting of plant species;

- Maintain the good condition of the plants: elimination of dry leaves, control of signs of parasites, regular controls of irrigation;

- Minimize the presence of invasive species;

- Regular pruning;

- Monitor plant health, vigor, and density;

- Maintain the good condition of the substrate, depth, and weight;

- Maintain the good state of the irrigation system;

- Monitor plant nutrition: keep a record of fertilization and PH values, before and after fertilization;

- Ensure drainage and removal of residues;

- Maintain the safety of the system: verify the anchorage points, the connections, and the points of light and water that the system uses;

- Maintain the waterproofing of the system.

b. Species selection guide:

Good knowledge of the plant species used in a living wall system allows maintaining their appearance over time. The selection of the species is made according to the objective of the project, the location, the exposure to the sun and shade, as well as the need to be able to develop in not very deep substrates.

The climatic condition of the place, from the point of view of humidity levels, minimum and maximum temperatures, as well as rainfall percentages, influences the type of species to be selected. Choosing, for example, species that are shade tolerant in those cases of indoor gardens or selecting species that are tolerant to high percentages of solar incidence in the case of fully exposed outdoor gardens, are useful decisions for the durability of the system.

A possible selection matrix for new users could be made up of knowledge about:

- The density of the species;

- The root type: superficial or fibrous shallow;

- The growth rate of the species;

- Resistance to direct solar incidence;

- Resistance to shade;

- Predisposition to parasites or infections;

- The growth of roots to the sides;

- The fragility of the stems;

- Dry biomass accumulation;

- Resistance to dryness (such as succulent, grey leaves or thick leaves);

- Resistance to ice;

- Toxicity to human contact;

- The development of spines.

c. System dismissal guide:

A material can be recovered or eliminated, two different concepts. In this classification, it is not considered as materials to be disposed of those by-products or secondary raw materials that satisfy certain criteria and conditions:

- That it is the product of an alternative process to that of its production;

- Its employability must be verified;

- That it satisfies the ideal environmental quality requirements to guarantee that its use does not give rise to emissions or impacts different from those already authorized;

- It must not be treated or preliminarily transformed to satisfy environmental quality requirements;

- That has a market value (Industrie e ambiente, 2017).

The reuse of materials brings important benefits to this type of systems in the field of sustainability. In the UK, for example, the reuse of materials translates into 19% of the total national ecological footprint, 23% of the total reductions in greenhouse gases and 420 million tonnes of materials in the recovery phase consumed. (Stockholm Environment Institute, 2017).

With some creativity and flexible design, the opportunities to incorporate recovered materials into new objects are wide. Therefore, the proposal to make a waste selection guide for living wall systems is based on giving a tool to the consumer, illustrating the inventory of materials in the system and the possibilities of reuse or not of each, starting from:

- General information about the material;

- Cases of application of recycled material;

- Comparison of raw material costs versus recycled material;

- Reduced carbon emissions from the reuse of such material.

2. Rainwater management:

The rainwater management responds to the requirements related to the use of rainwater recovery systems in the construction phase. The use of vegetation for rainwater bring more surfaces that can contribute to the collection of water, which would also help to reduce the current urban problems. Cities in the world are worried about forecasting floods during rainy days, the vegetation provides the function of acting as a natural regulator of rainwater, starting from the reuse for irrigation, thus increasing the time between the climatic event and the discharges of water. Rainwater can be used to irrigate vertical and horizontal gardens without any treatment.

The rainwater recovery system can be operated in two ways:

- *Mechanically (injection pump)*, the tank can be installed on the same level as the vertical/horizontal garden;

- *For gravity*, the tank should be installed at a lower level than the vertical/horizontal garden.

And disposed in two possible configurations:

- *Collection in a sump*, a gutter is installed in the lower part of the system, with the function of recovering the water and the excess solution.

- *Integrated into the system*, a system in which each module is connected to a reservoir to carry it back to the sump. This requires a high number of components, but at the same time offers greater flexibility in the maintenance of the system.

3. Use of renewable resources

The use of renewable sources responds to the requirements related to the maintenance of the system and the need to limit the energy consumption from non-renewable sources during the maintenance phase. The building envelope, instead of being considered as an element of protection, also has the function of mediating the external climatic conditions, heat fluxes and relative humidity, whit reference to the daily and seasonal fluctuations, trying to advantage them in order to bring thermal well-being indoor environments. Whit the use of a living wall system and a passive solar system, the building as a whole can be a passive system.

4. Standardization of production processes:

The standardization of the production processes responds to the requirements related to the reduction of costs associated with the assembly, the use of integrated function elements and the reduction of the number of materials during the production phase. The standardization of the product allows the producer to reduce production costs, benefiting from economies of scale in the production of single components, the reduction of sales time due to the possibility of simultaneously producing different elements, and increase the flexibility of the final product. (Lanzara R et al., 2002) The implementation of a standardized modular strategy allows increasing the adaptability, quality, and innovation of the product.

Among the elements on which market research and functionality analysis can be developed were:

- Module hooking system: hooks and release brackets

- Hooking systems to the support structure

- Supporting structure: stiffening frame

- Connections: snap, screws, rivets or adhesives

5. Design out waste:

The design out waste responds to the requirements related to prioritize the toxic materials and to select incinerable and combustible materials during the dismissal phase. More efficient use of materials would greatly contribute to reducing the environmental impacts of prototype construction and production, including reducing the demand for landfills and deplete natural resources. This would also contribute to economic efficiency.

The design out waste strategy proposes an improvement in reducing waste from the design phase, and is based on five fundamental principles:

- Design for reuse and recovery

- Design for off-site construction

- Design for materials optimization

- Design for waste efficient procurement

- Design for deconstruction and flexibility

City Hall of Venlo, Kraaijvanger Architects

Within these 5 principles are strategies for the reduction of waste and costs associated with new projects, it should be noted that they are applicable to any type of project. In this case, the ones applicable to a living wall system are:

- *Design for reuse and recovery:* reuse of components and materials has great potential to reduce environmental impacts, one of them is embodied energy (EE), embodied carbon (EC) and waste. In the particular case of the living wall system, among its components can be recycled:

  a. The external layer of containment of plants, usually made of felt or geotextiles;

  b. The supporting structure, usually made of plastic or aluminum;

  c. The substrate, in the mix, are discards, fibers and organic materials that can be reused.

- *Design for materials optimization*: This principle is based on a series of strategies that designers should consider as part of the design process. These strategies are based on decisions focused on the efficiency of the materials, so as to reduce the number used, as well as reducing waste. Within this process two main areas are developed:

  a. Simplification and standardization of materials and components

  b. Coordination between the dimensions of the parts

- *Design for deconstruction and flexibility:* Designers must consider the properties of each material, and the possibility of recycling at the end of the life cycle. The application of this principle in the field of deconstruction and flexibility of living wall systems should be done in the early stages of design, to explore options and evaluate the practicality of each one.

To evaluate waste reduction opportunities in the assembly phase of the module, the following questions should be answered:

a. Is the design adapted to different purposes during the life cycle of the module?

b. From the design point of view, is it possible to easily carry out the necessary maintenance and replacement of product components?

c. Can the materials used be recycled or reused?

d. Is the module easy to assemble and remove?

The method and principles of design can be an advantage in the life cycle of these technologies, as well as offering the opportunity for them to become systems accessible to anyone, sustainable in time, and reduced costs.

CONCLUSION

The vertical green can be conceived as a synthesis between landscape and architecture. This has a duality, on the one hand, it allows to unite constructed volumes to the natural landscape mimicking them and minimizing the presence of the industrial aspect, and on the other hand, it allows to hide aesthetically difficult to handle objects such as technical or infrastructure installations. This line of ideas opens up the opportunity to establish the living wall system as a technical element of the architectural project.

The use of these systems both in urban planning and in the design of buildings and internal spaces gives a sense of sustainability, and awareness of the reduction of emissions, and the possibility of ensuring quality spaces and welfare. It is important to highlight the economic accessibility of these solutions, to the point of being justifiable as a social investment.

It is necessary to deepen research and develop a real integration between vegetation and the built environment, which does not just mean a label, and which can remain naturally during all phases of a building's life cycle. It is, therefore, a challenge to develop prototypes that limit maintenance costs, but that are also designed from the point of view of environmental conservation and the participation of the user in the management and maintenance process, all this through interdisciplinary research that encompasses biology, agronomy, climate study, engineering, and architecture.

It can be said that within the living wall system there are two areas: technological and environmental, associated with nature and operation, that can be improved through some alternatives: proposal of guides "Do It Yourself" to optimize the maintenance an dismissal of the system, the rainwater management, the use of renewable resources for energy savings, the standardization of some components to reduce costs and materials and, finally, a module design through design out waste premises. Alternatives that determine different expectations in the development of these systems, it is expected not only the good operation of all its parts but also the efficiency of the entire system at the level of a facade and its interaction with the environment.

REFERENCES

A., B. (2003) Pareti verdi: linee guide alla progettazione. Edited by S. E. AS5.

Azkorra, Z. et al. (2015) 'Evaluation of green walls as a passive acoustic insulation system for buildings', Applied Acoustics. Elsevier Ltd, 89, pp. 46–56. doi: 10.1016/j.apacoust.2014.09.010.

Bit, E. (2010) La vegetazione per le chiusure verticali. Università degli Studi di Ferrara.

BRE Global (2014) 'The Green Guide', The Green Guide, 44(1), pp. 1–5. doi: 10.1007/s13398-014-0173-7.2.

Chel, A. and Kaushik, G. (2013) 'Renewable energy technologies for sustainable development of energy efficient building', Alexandria Engineering Journal. Faculty of Engineering, Alexandria University. doi: 10.1016/j.aej.2017.02.027.

Culnane, N. et al. (2014) Growing green guide.

Diamond, M. L. and Hodge, E. (2007) 'Urban Contaminant Dynamics: From Source to Effect', Environmental Science & Technology. American Chemical Society, 41(11), pp. 3796–3800. doi: 10.1021/es072542n.

Dunnett, N., Kingsbury, N. (2008) Planting Green Roofs and Living Walls. Portland, Or.

Giordano, R., Montacchini, E. and Tedesco, S. (2013) 'L ' approccio al ciclo di vita nella progettazione , produzione e monitoraggio di una facciata verde', (I), pp. 184–190.

Giordano, R., Montacchini, E. and Tedesco, S. (2016) 'Living Wall Systems : verso la sostenibilità Ricerche e sperimentazioni', pp. 5–14.

Gourdji, S. (2018) 'Review of plants to mitigate particulate matter, ozone as well as nitrogen dioxide air pollutants and applicable recommendations for green roofs in

Montreal, Quebec', Environmental Pollution, 241, pp. 378–387. doi: 10.1016/j.envpol.2018.05.053.

Industrie e ambiente (2017). Available at: http://www.industrieambiente.it.

Klingberg, J. et al. (2017) 'Influence of urban vegetation on air pollution and noise exposure – A case study in Gothenburg, Sweden', Science of the Total Environment, 599–600, pp. 1728–1739. doi: 10.1016/j.scitotenv.2017.05.051.

Mariani, L. et al. (2016) 'Climatological analysis of the mitigating effect of vegetation on the urban heat island of Milan, Italy', Science of the Total Environment. Elsevier B.V., 569–570, pp. 762–773. doi: 10.1016/j.scitotenv.2016.06.111.

Olivieri, F. (2013) Caracterización experimental y modelo predictivo de las prestaciones termicas *de una pared verde. Universidad Politécnica de Madrid.*

Ottelé, M. et al. (2011) 'Comparative life cycle analysis for green façades and living wall systems', Energy and Buildings, 43(12), pp. 3419–3429. doi: https://doi.org/10.1016/j.enbuild.2011.09.010.

Pan, L. and Chu, L. M. (2016) 'Energy saving potential and life cycle environmental impacts of a vertical greenery system in Hong Kong: A case study', Building and Environment. Elsevier Ltd, 96(July), pp. 293–300. doi: 10.1016/j.buildenv.2015.06.033.

Pérez-Urrestarazu, L. et al. (2016) 'Vertical Greening Systems and Sustainable Cities', Journal of Urban Technology, 0732(August), pp. 1–21. doi: 10.1080/10630732.2015.1073900.

Pérez, G. et al. (2011) 'Green vertical systems for buildings as passive systems for energy savings', Applied Energy, 88(12), pp. 4854–4859. doi: https://doi.org/10.1016/j.apenergy.2011.06.032.

Perini, K. et al. (2011) 'Greening the building envelope , façade greening and living wall systems', Open Journal of Ecology, 1(1), pp. 1–8. doi: 10.4236/oje.2011.11001.

Perini, K. et al. (2017) 'Quantification of fine dust deposition on different plant species in a vertical greening system', Ecological Engineering, 100, pp. 268–276. doi: 10.1016/j.ecoleng.2016.12.032.

Perini, K. and Rosasco, P. (2013) 'Cost–benefit analysis for green façades and living wall systems', Building and Environment, 70, pp. 110–121. doi: https://doi.org/10.1016/j.buildenv.2013.08.012.

Pugh, T. A. M. et al. (2012) 'Effectiveness of green infrastructure for improvement of air quality in urban street canyons', Environmental Science and Technology, 46(14), pp. 7692–7699. doi: 10.1021/es300826w.

Serra, V. and Politecnico, D. (2009) 'Vertical Greening Systems and Urban Heat Island related aspects : outcomes of a research project Vertical Greening Systems Benefits of VGSs', (Weinmaster).

Sheweka, S. M. and Mohamed, N. M. (2012) 'Green facades as a new sustainable approach towards climate change', Energy Procedia. Elsevier B.V., 18, pp. 507–520. doi: 10.1016/j.egypro.2012.05.062.

Sheweka, S. and Magdy, N. (2011) 'The living walls as an approach for a healthy urban environment', Energy Procedia, 6, pp. 592–599. doi: 10.1016/j.egypro.2011.05.068.

Stockholm Environment Institute (2017). Available at: https://www.sei.org.

Tamási, A. and Dobszay, G. (2015) 'Requirements for Designing Living Wall Systems – Analysing System Studies on Hungarian Projects', pp. 78–87. doi: 10.3311/PPar.8337.

Tatano, V., (2008) Verde: naturalizzare in verticale. Edited by Maggiole Editore. Environscapes.

Tedesco, S., Giordano, R. and Montacchini, E. (2016) 'How to Measure the Green Façade Sustainability? A Proposal of a Technical Standard', Energy Procedia. Elsevier

B.V., 96(October), pp. 560–567. doi: 10.1016/j.egypro.2016.09.100.

Voogt, J. A. and Oke, T. R. (2003) 'Thermal remote sensing of urban climates', Remote Sensing of Environment, 86(3), pp. 370–384. doi: 10.1016/S0034-4257(03)00079-8.

Xing, Y., Jones, P. and Donnison, I. (2017a) 'Characterisation of nature-based solutions for the built environment', Sustainability (Switzerland), 9(1), pp. 1–20. doi: 10.3390/su9010149.

Xing, Y., Jones, P. and Donnison, I. (2017b) 'Characterisation of Nature-Based Solutions for the Built Environment', Sustainability, 9(1), p. 149. doi: 10.3390/su9010149.

Lausane. Suiza.
I.de Felipe

CHAPTER 7

CONTROLLED ENVIRONMENT ECOSYSTEMS

CLOSING THE NUTRIENT CYCLES IN URBAN FOOD PRODUCTION

Radu M. Giurgiu[1,2], Rares C. Nistor[1], Alexander van Tuyll[3], Seppe Salari[3,4], Zjef van Acker[5], Manfred Köhler[6] and Dan C. Vodnar[1]

[1]University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania
[2]MELiSSA Foundation, Belgium
[3]Wageningen University and Research, The Netherlands
[4]SmartCrops B.V., The Netherlands
[5]Pad en Stoel, Belgium
[6]University of Applied Sciences, Neubrandenburg, Germany

1 SUMMARY

This chapter explores a novel way of farming within the city, inspired by processes occurring in nature. Starting from the current state of vertical farming, we focus on the inputs and outputs of these systems, and how closing the loops can lead to a more sustainable and resilient way of producing food. The AMI concept is introduced as an alternative to the conventional linear models of controlled-environment agriculture. The components of AMI systems are described individually, followed by three potential configurations of ecosystem food production systems. The environmental sustainability of these systems occupies the majority of the chapter, but their economic potential is also explored. The chapter ends with a case study, the Plantgeek project: a research project on aquaponics, the first link of the AMI concept.

2 KEY WORDS

Ecosystems, controlled environment, sustainability, urban farming, aquaponics, mushrooms, insects, waste to value.

3 INTRODUCTION AND GOALS

This chapter aims to delve into urban and vertical farming as a follow up to the chapter published in the previous WGIN book. In the first segment, we will describe the main elements of indoor food production with an emphasis on aquaponics, the technology of growing fish and plants in symbiosis, in which fish waste is transformed by bacteria into nutrients for the plants. The second part proceeds with an analysis of the multitude of facets of ecosystem food production, with respect to the input/output streams and balances, the dynamics of the processes, and how technology can be both the tool in generating data for a better understanding of the systems, and also the mean to optimise the systems based on the acquired knowledge. We will also give a broad overview of the economics and how these systems can have a meaningful impact in the future of urban food production, ending up with analysing the concept by narrowing down the focus over a case study, the Plantgeek research project.

4 VERTICAL / URBAN FARMING, ADVANTAGES AND CHALLENGES

Vertical farming (VF) is still part of a growing popularity trend as an emerging food production technology that has a number of advantages over the conventional agriculture /citekalantari2018opportunities. VFs are responding to global challenges such as population growth, rapid urbanisation, the adverse effects of climate change, land scarcity, and water usage. It does this by implementing a technology of growing plants without soil, in a nutrient-rich solution, in a closed system. The biggest advantage of this practice is the land-use efficiency obtained through stacking layers of crops instead of just one plane, as is the case with conventional agriculture. VFs also use a controlled environment to carefully monitor and adjust the growing process. However, this comes at the expense of the energy consumption and infrastructure costs which many sceptics are bringing into the debate. On the other hand, VFs can grow food inside the city, cutting out transportation and delivering fresh produce directly to consumers. Currently, using this technology, there is still a limit to the range of crops that are economically viable. The projection of most people is that VF will not completely replace conventional agriculture. Instead, it will be an important addition in the transition towards a truly sustainable food system. However, for this goal, VFs need to become more integrated with their environment and adopt the principles of ecosystems thinking.

5 URBAN FARMING 2.0 - CONTROLLED ENVIRONMENT ECOSYSTEMS; THE AMI CONCEPT

This chapter describes an improved concept for indoor, urban, and vertical food production, with respect to resource management and integration with the environment. AMI (pronounced like 'Jamie') stands for 'aquaponics, mushrooms and insects', and is based on complex natural ecosystems. With AMI, vertical farming is involving more organism aiming to use resource more sustainable and close the nutrient cycles.

Two examples of this thinking: (1) VFs rely on energy, synthetic fertiliser for the nutrient solution that is delivered to the plants, the nutrients being extracted from other, mostly fossil, sources. (2) Even made more circular through aquaponics (which combines fish and plants by transforming the waste of the fish to nutrients for the plants), there is a need for other external inputs which are not part of the circular flow. Fish feed is just one of these.

The AMI concept is an iterative approach on designing urban food production systems, starting from available resources and building on with loops that process and make value out of waste. It is a combination of the circular economy (Ellen MacArthur Foundation), the blue economy (Gunther Pauli), and ecosystems thinking, applied to indoor urban farming.

Components

The production of vegetables, fish, mushrooms, and insects together would already be a great start in using the principles behind the AMI concept. That said, there are

Table 1: An overview of the four trophic levels described, each with examples. These four trophic levels are required to perform the same functions as done in natural ecosystems. The examples given here are nowhere near exhaustive.

Trophic level	Description	Examples
Primary producers	Convert abiotic energy, usually light, into chemical energy. Primary producers are the only trophic level where chemical energy is added to the system.	Plants Algae Cyanobacteria
Herbivores	Eat living plant tissue, concentrating energy and proteins.	Animals
Carnivores	Eat animal tissue, converting it into different animal tissue.	Animals
Detrivores	Live off decomposing matter (detritus). Recover energy and protein.	Insects Fungi Worms Bacteria

far more organisms and subsystems that could be beneficial, depending on the context.

A core feature of AMI systems is that they use the outputs of one subsystem as inputs for the next. In natural ecosystems, this is done by different organisms with different functions, also known as trophic levels. AMI systems mimic nature by carrying out the exact same functions that occur in natural ecosystems. This is useful to bear in mind when deciding on which subsystems to add to an AMI system. Although the examples presented here cover all trophic levels of an ecosystem, there are plenty more possibilities, which are only likely to work if all levels are occupied. The four main trophic levels are: primary producers, herbivores, carnivores, and detrivores. These are explained in the table below. The latter three levels are similar in that they recover, convert, and concentrate existing chemical energy. On the other hand, primary producers are the only organisms capable of adding chemical energy to the system.

5.1 Insect cultivation

Insects and their larvae are highly efficient in producing protein. They are also very diverse - ranging from crickets to mealworm larvae, each with different requirements.

One of the most versatile and protein-efficient insects is the black soldier fly (BSF). BSF larvae are detrivores, able to grow on almost any form of organic waste, including animal manure. At the same time, they can reduce the pathogen load in their substrate. These properties make BSF larvae an ideal workhorse for AMI systems, as the primary site where protein is recovered from waste. To recover protein efficiently, larvae should be harvested before they reach their final instars, for two reasons. Firstly, too much energy goes to chitin production in later instars. Secondly, the larvae stop feeding, thereby releasing their own stored chemical energy.

In theory, BSF larvae could be fed to humans. However, it is usually more convenient to use BSF larvae as an animal feed, passing their protein on to other parts of the AMI system. BSF larvae are also a sustainable source of protein, since their environmental impact is lower than that of conventional sources such as soy. Furthermore, this means less feed needs to be imported, preventing the local nutrient balance from being too high (as is currently the case in the Netherlands, for example).

Insect cultivation produces a number of by-products. The first by-product is insect frass. Depending on the substrate used, this can be anything from a viscous liquid to moist crumbs of insect manure. Insect frass is rich in nutrients and organic matter. This can be used as a fertiliser or soil amendment, or to grow earthworms.

The other by-products are carbon dioxide, water vapour, and ammonia. These three by-products are released into the air. Carbon dioxide can be used by plants. However, due to the presence of ammonia in this air, directly pumping it to plant production facilities is only advisable for low concentrations of ammonia. That said, some types of algae are able to use ammonia as a nitrogen source. This makes the air from BSF larvae production potentially ideal for these algae.

Table 2: An overview of the main inputs, factors, and outputs for insect production.

Inputs	Factors	Outputs
Biomass	Temperature	Larvae
Oxygen	$[O_2]$	Residue/frass
(Eggs)	Relative humidity	CO_2
(Light)	$[CO_2]$ Illuminance	NH_3

5.2 Aquaculture

Aquaculture covers organisms with characteristics more diverse than those of insects: fish, shellfish, crustaceans, and more. Despite these possibilities, this subsection will focus on the production of (fresh-water) fish only.

Table 3: An overview of the main inputs, factors, and outputs for fish aquaculture

Inputs	Factors	Outputs
Feed	Temperature	Fish
Oxygen	Dissolved oxygen	CO_2
Water	pH Stocking density	NH_3 Aqueous ions Solid waste

The main input (other than water, oxygen, and energy) in fish aquaculture systems is fish feed. The requirements of this feed depend on the species cultivated. In general, feed is given daily at around 1-3% of the current standing stock. Fish feed must be high in protein. This makes insect larvae an appropriate feed. A limitation of insect larvae is their chitin exoskeletons. Despite research showing benefits of chitin supplementation to fish health [5], in high amounts, the exoskeletons are either not digested or simply rejected. Fish also require omega 3 fatty acids in their diet. Currently, this is supplied through fish-meal, obtained through fishing. In natural ecosystems, algae are the primary producers of omega 3. Feeding algae directly to fish (thereby bypassing fish-meal) is therefore more sustainable, as it reduces pressure on marine ecosystems.

Being heterotrophic animals, the outputs of fish are similar to that of insects. Besides carbon dioxide, fish produce soluble and insoluble (solid) waste. To ensure conditions remain suitable for the fish, these two outputs must be removed on a regular basis.

Solid waste is removed through a filter. Although this is not done in conventional aquaculture systems, this solid waste can be fed to earthworms, insects, or other aquatic organisms, like shrimp. Failing that, solid waste can be used as a soil amendment. Soluble waste, on the other hand, can be used to fertilise plants or algae. If used for plants, ammonia - the most abundant soluble output - must be converted into nitrate through nitrifying bacteria. The nutrient profile of fish waste will depend on the feed used. This presents a trade-off between efficient aquaculture and optimal plant nutrient supply.

5.3 Plant production

Though plants have varying requirements, the principles of their cultivation are largely similar. Whilst other organisms so far discussed recover and concentrate chemical energy and produce carbon dioxide, plants introduce new chemical energy into the system and take up carbon dioxide, whilst removing nutrients from water. This, of course, is done through photosynthesis.

Apart from carbon dioxide and light, plants require water and nutrients. Water and nutrients are supplied through a growing medium, but can also be directly supplied, as is done in hydroponics. The growing medium should have the correct pH, and nutrients must be present in the right amounts. In aquaponics systems, there may be a nutrient imbalance, requiring supplementation and/or leaching.

Table 4: An overview of the main inputs, factors, and outputs for plant production

Inputs	Factors	Outputs
Light	Wavelength	Vegetables/ fruits
Carbon dioxide	Photoperiod	Lignocellulose
Water	Light intensity	Water vapor
Nutrients (NPK)	pH Nutrient concentrations Temperature Relative humidity [CO_2]	Leach water

Plant production has many non-food outputs. The first is oxygen, which can be used in any heterotrophic process. Water vapour is also produced through transpiration. This can either be recovered or used to humidify mushroom production chambers. There are also inedible parts of the plant - stems, roots, and so on - which are made of lignocellulose. The only organisms able to efficiently use lignocellulose are fungi and some micro-organisms. Lastly, soilless growing systems produce leach water, often due to the build-up of sodium. This can be diverted to algae, which are far more sodium-tolerant than plants.

5.4 Fungiculture

Fungi are special because they are the only organisms listed here that can digest lignocellulose. This is an important property, since lignocellulose makes up a significant proportion of the biomass and chemical energy in plants.

There are 3 steps in the industrial production of mushrooms: (1) spawn production, (2) substrate production and (3) the production of fruiting bodies.

In phase one, fungal spores are inoculated into the growing medium. Fungi are extremely sensitive to contamination - be it bacterial, viral or through other fungi. Therefore, the spawn growing medium must be sterilised. This is usually done through a process known as autoclaving, but can also be done through pasteurisation. In the second phase, the spawn is added to this specific sterilised substrate.

Table 5: An overview of the main inputs, factors, and outputs for mushroom production

Inputs	Factors	Outputs
Lignocellulose	Temperature	Mushrooms
Oxygen	[O_2] Relative humidity	CO_2

For the substrate, a nitrogen source is also often necessary. In recent years multiple companies have been using coffee grounds - an abundant waste stream - as a source of nitrogen. In substrate production, most fungi require dark, humid conditions and a specific temperature for optimal growth. Optimal conditions and substrate depend on the species of fungi cultivated.

Under other conditions than the conditions of substrate production, the fungus produces fruiting bodies - mushrooms - in multiple 'flushes', usually around three.

Fungi grow on lignocellulose by secreting digestive enzymes, transforming around 30 percent of the substrate mass into fruiting bodies. As a result, used substrate from fungi can be digested by insects, for example, since lignocellulose gets broken down.

5.5 Algaculture

Taxonomically speaking, the term 'algae' is broad and ambiguous, referring to both

Vegetables in urban orchard. I de Felipe

macroalgae and microalgae, which are respectively multicellular and unicellular. Generally speaking, the term excludes cyanobacteria, despite important species (such as those called 'Spirulina') falling under that term and being similar to algae in their cultivation. This section covers both algae and cyanobacteria, hereafter referred to as 'algae'.

Like plants, algae take up water, nutrients, and carbon dioxide, producing biomass and oxygen. However, algae are more versatile in multiple ways. Firstly, unicellular algae can be housed in many ways - pipes, tanks, and so on - allowing for optimal light interception. Secondly, most algae are more tolerant to high concentrations of ions (including sodium) than plants. This makes them ideal for using brackish water from other processes within the AMI system. Lastly, algae can produce a high-quality source of omega 3 fatty acids. This allows for aquaculture without animal-based inputs such as fishmeal.

In theory, the culture of algae has no outputs other than algal biomass and oxygen. That said, current systems do discard water when harvesting. This is because harvesting involves removing a certain amount of water from the system and concentrating the algae. The water removed during concentration gets discarded.

5.6 Vermiculture

Vermiculture refers to the cultivation of earthworms. In the context of AMI, earthworms can be used as an extra step to further recover and concentrate proteins from black soldier fly larvae castings. These earthworms can then be fed to fish, for instance. The earthworm castings can be used as a fertiliser or soil amendment. Although the potential of this element is evident for the AMI systems, this part needs further research for getting more data on how it can be implemented in the complex ecosystem food production.

6 NUTRIENT CYCLES IN ECOSYSTEM FOOD PRODUCTION SYSTEMS (AMI SYSTEM)

As discussed in the previous section, AMI systems have the potential to produce food with waste, by harnessing the benefits of the ecosystems approach. The key to a successful cooperation between different growing systems, stands in understanding the relations between them in terms on inputs and outputs. This section is describing possible configurations, and possible external waste streams to be used as resources for AMI systems. Production estimates and assessments in the context as the driver for the system design, will be given.

6.1 Input/Output cycle, possible configurations

As previously discussed, there are multiple possibilities when it comes to setting up an AMI system. In this subsection, three possibilities are presented that range in complexity. With every added component, the amount of knowledge and decisions to be made when running the system becomes orders of magnitude larger. In practice it may be wise to start with aquaponics, since it is the most well-known part of the AMI approach, and slowly build from there. When used correctly, more components allow for the system to run more efficiently and make better use of different wasted resource streams.

In the following diagrams, only flows of nutrients and organic matter are shown. For the sake of clarity, energy, humidity, oxygen, and carbon dioxide are omitted.

6.1.1 Configuration 1: Aquaponics, Mushrooms, Insects

In this first configuration, black soldier fly larvae are used to process incoming organic waste (e.g. food waste, livestock manure, or inedible plant parts). These larvae are fed to the fish in an aquaponics system. Insect frass can also be used for plant production. Any remaining lignocellulose from plant production (or external sources) can be used for mushroom production.

Using nutrient mass balances and conversion ratios for the different subsystems and their inputs, a tonne of fruit and vegetable waste could produce approximately the following, using this configuration:

- 55 kg of tilapia fish
- 615 kg of leafy greens
- 6 kg of oyster mushrooms

These production figures may well be higher in reality, since the above figures came from calculations where mushroom residue was not re-introduced into the system. It should be also noted that these numbers should not be compared with production figures from respective stand-alone conventional

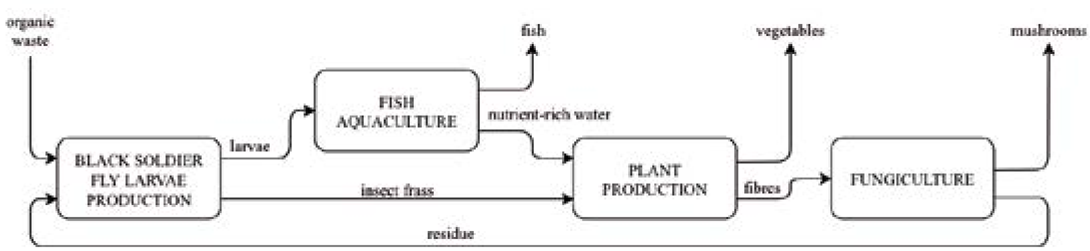


Figure 1: An overview of the inputs and outputs of each subsystem in a configuration of aquaponics, mushrooms, and insects. Carbon dioxide, energy, and water flows have been omitted

cultivation systems (aquaculture and agriculture). The primary goal is not to produce more per square metre or animal, but to transform waste into food.

6.1.2 Configuration 2: AMI with Extended Heterotroph-Waste Usage

Configuration 2 is similar to the AMI system shown in Configuration 1, but contains two new subsystems. This allows for internal waste streams to be used more effectively.

Black soldier fly larvae produce insect frass and ammonia as waste products. Rather than going to plant production, insect frass goes to earthworm vermiculture. This is a good way to make use of the energy that the frass still contains. These worms can be fed to fish as a second protein input. Ammonia in the air of the larvae production system can be sent to algaculture, producing algae and providing a source of omega 3 for the fish. Algaculture can also use leach water from the plant production system.

The fish themselves produce solid waste as well. This still contains energy, which can be used to produce shrimp. Nutrient-rich water from the shrimp can be sent to plant production. If this water is too saline, it could be sent directly to algaculture (a connection that is not drawn here). A lot of decisions would have to be made in such a system, and best practices are not yet known.

6.1.3 Configuration 3: Focusing on Sewage Water

Configuration 3 shows an AMI system similar to the two systems previously presented, with the addition of sewage as an indirect input. This flowchart is based on a conceptual design done by team Green Spark for Wageningen University's 2018 Urban Greenhouse Challenge.

Sewage - in particular, black water - is an important source of organic waste. Like the organic waste discussed so far, it contains energy and nutrients. The only issue is that black water is unpredictable, and can contain a plethora of unwanted chemicals such as drugs. The same applies to urine ('yellow water'). As a result, this waste cannot be fed directly to the AMI system. Different steps have to be taken. Waste streams such as these are analysed in the framework of http://melissafoundation.org/space exploration for life support systems where waste water is reused, and nutrients are recovered and recycled in producing food, oxygen and water for the astronauts.

Black water is first fed to a biodigester, producing methane, which can be used as a source of energy and/or carbon dioxide. This is the first step in using the energy from this waste. The second step involves pyrolysis. Pyrolysis involves heating the biodigester sludge to high temperatures - hundreds of degrees Celsius - under anaerobic conditions. This is known to produce more energy than it uses, and results in biochar. At the same time, pyrolysis destroys the majority of unwanted organic compounds in the black water.

Yellow water, combined with magnesium is passed through a struvite precipitator. This produces struvite, a slow-release plant fertiliser.

The next step involves the biochar from pyrolysis. Biochar can be used for plant production: either as a soil amendment, or in substrate if sawdust and soil are added. When being used in substrate, biochar has properties similar to peat moss.

6.2 Possible waste streams

The strong point of AMI systems is the ability to take waste streams as an input and use their energy and nutrients to produce food. Therefore, choosing the right waste streams is just as important - if not more important - than the system itself. To give an idea of the current uses and restrictions, some of these waste streams and their challenges are presented here.

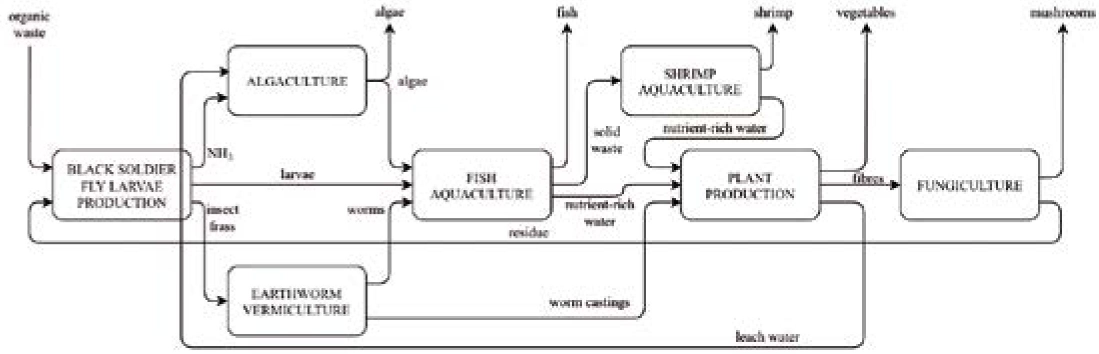


Figure 2: An overview of the inputs and outputs of each subsystem in a configuration of aquaponics, mushrooms, and insects, with other cultivation systems such as vermiculture, shrimp culture and algaculture. Carbon dioxide, energy, and water flows have been omitted

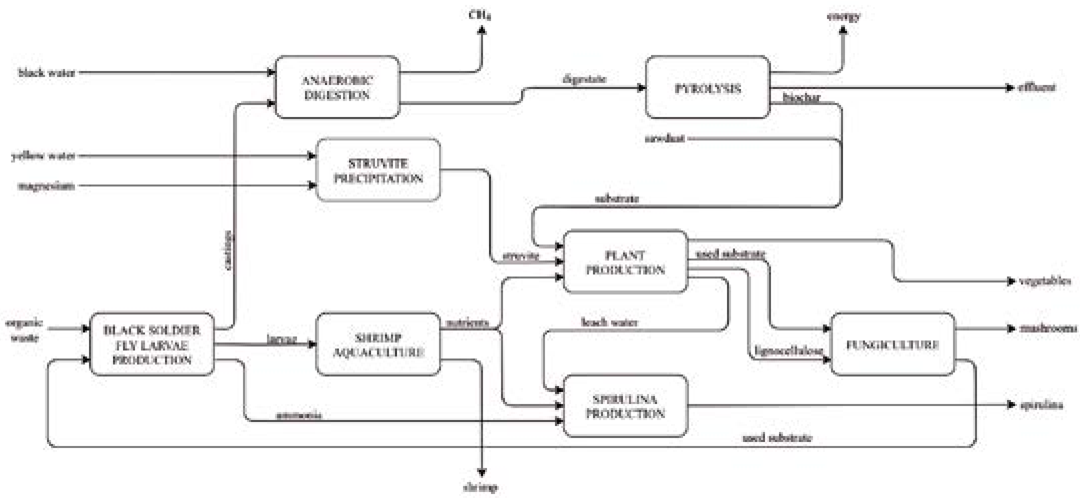


Figure 3: The input/output flow between aquaponics, mushrooms, and insects with other cultivation systems and added input from treated sewage water. Flows of carbon dioxide, water, and energy (unless a net output) have been omitted

The best waste streams for AMI systems are produced on a large scale and have a predictable and consistent quality and quantity. Currently, under European Union legislation, there are restrictions on waste streams, particularly when being fed to insects [6]. However, these are expected to change. Logistics are another challenge, as plenty of these waste streams are predictable but too dispersed.

6.2.1 Coffee grounds

Coffee grounds are a good source of nitrogen for mushrooms. Currently, a number of companies worldwide (such as Permafungi in Belgium, Funghi Espresso in Italy & Rotterzwam in the Netherlands) are using coffee grounds to grow Oyster mushrooms. Coffee grounds are an appropriate waste stream due to their consistency, but also because they are sterile after making coffee. The main challenge lies in logistics, as coffee grounds are produced in small amounts in many places, which mostly also do not yet have a workflow that keeps the coffee grounds sterile.

6.2.2 Animal manure

Unlike coffee grounds, most animal manure is produced on a large scale and is therefore easy to collect. Animal manure contains energy and nutrients, and can be therefore fed to detrivores. Research shows that black soldier flies are able to decrease the bacterial load in chicken manure whilst converting it into protein that can be used again [4]. This is especially useful, as it leads to a more closed nutrient cycle, helping combat the current nutrient surplus in the environment of many Western European countries. The only limitation is that current EU legislation does not allow the feeding of converted manure to animals.

6.2.3 Brewer's spent grain

Brewer's spent grain is approximately 20% protein and 70% fibre in terms of dry matter. This makes it an excellent substrate for growing mushrooms, especially due to its consistency. Currently, a number of organisations are using spent grain to grow mushrooms. Le Champignon de Bruxelles in Anderlecht, growing shiitake mushrooms, is one of them. They also use this as a way to demonstrate the principles of circular farming to locals.

6.3 Production and quality of the products

6.3.1 AMI systems and yields

As described in the previous section, there is a very high number of possible combinations of AMI systems, starting from waste streams and building up by reusing as many resources as possible, towards a self-sufficient system in terms of at least the inputs/outputs at the nutrient level. In this context, the producer and the consumer become connected in a self-sustaining ecosystem. This spectrum of choices is a blessing for resilience, the AMI system being designed according to each specific case. At the same time, adding complexity and layers to an AMI system has its drawbacks. Having just one growing system and one type of species, the entire environment can be controlled, resulting in optimal yield. One can do that too for AMI systems, if each growing system is decoupled resulting in a discontinuous cycle. In general, however, AMI systems aim to create indoor ecosystems that can work as one, replicating natural processes and, aided by technology, becoming as efficient as current means allow. This type of setup would come with some compromises, leading to results that could not compete with the production figures of conventional VFs or even conventional agriculture, when simply looking at output within the production system and excluding externalities.

6.3.2 The quality of the products

The yields are the main figures focused on by farmers, because quantity pays. There are different ways of categorising cultivation methods, such as organic farming that comes with allegedly higher quality products and lower environmental impact that justifies the higher prices. VFs are in regard to organic certification at contradicting terms, depending on the geolocation, with the United States allowing soilless cultivation in this category whereas European countries would not give the same certification if produce is not cultivated in soil. This duality shows the lack of data that would settle this kind of debates. Without spiralling down into this, it is important to see what AMI system would bring to the market in terms of quality of produce. Having the most important foundation on waste streams, AMI system can be considered as having lower environmental impact than the conventional alternatives. There is still the need for more research that deals with the quality of the products in these complex ecosystems. Even if there are no complex AMI systems in the market, yet, the inputs and outputs in terms of quantities can be easily calculated and modelled based on the knowledge of each individual system. The 'travel' of nutrients from one system to the other and its influence on the quality of output that will reach the market is less understood. In theory, AMI produce should be of high nutritional value, and even a sub-optimal environment can actually be seen as positive by stressing the crops just enough to produce more antioxidants. These topics need further research before it can be recommended as a more healthier option not just for the environment, but for consumers as well.

6.3.3 Resilience in disease management

An increasing number of consumers are becoming increasingly concerned with the issues of pesticides used in agriculture and how that can affect their heath and the environment [3]. Even in organic farming, some pesticides labelled as 'natural', are used. In VFs, due to the hydroponic technology, a pathogen can create mayhem if it is introduced in the culture. Therefore the workers are suited up in lab coats, hair covers, and gloves. Although these preventive practices help ensure food safety, it can look alien to consumers. With the AMI concept being relatively new as an agricultural practice, more research should be done to address these issues. That said, looking at systems existing today, they seem to be very resilient. Having a stable ecosystem takes time, but once established, it deals well with a continuous adaptation to the environmental changes or subtle shifts that could otherwise create a context for diseases in more sterile systems [2].

6.4 Context and system design

The complexity of the AMI systems can be an obstacle in persuading the farmers to adopt the concept. The unknowns of combining different organisms in food production present challenges that are being embraced by scientists, but less so by farmers, who

La Havana. Urban orchard. I. de Felipe

need certainty and viable business models. At the same time, the complexity of different organisms and technologies that can transform waste into value will help reach a higher degree of resilience. To make a parallel with conventional VFs, which are more standardised in species grown, technologies such as LED lighting or formulations of nutrient solutions, have the drawback of a one-size-fits-all approach. VFs can have successful outcomes in specific scenarios and business models, but could just as easily fail in other cases (as many have). AMI systems are more resilient because they offer a large palette of loops within loops. Conventional VFs start from a crop to be produced - chosen based on technical capabilities and market conditions - whereas AMI systems should start with an existing phenomenon in their environment: waste. Waste, generally considered a burden, could be the start of designing new systems. Outputs seen as useless can become valuable inputs for one organism and then the quantities, quality and logistics can be designed for the first loop. Similar steps are then involved when more organisms are added, adding complexity until this is no longer worthwhile for the business.

6.4.1 AMI state of the art

A logical question following the previous statements would be: 'Why aren't there more AMI systems operating at the moment against the VFs or even conventional agriculture farms'? If AMI systems are so great at producing food, while reducing waste and managing resources better than any other food-producing technology, what are the factors that have prevented them from gaining prominence? To answer these questions, we have to look at the business models of the first vertical farms. Around the globe, there are a number of companies associating their name with this emerging industry. Very few are capitalising on the plants as a main revenue stream. Most of them, especially in Europe, are getting revenue from selling the technology on which the farms are based. The reason behind this is based on the difficulty to compete with conventional agriculture on the price of the end-product (the plants). That does not necessarily position VFs as unsustainable economically but it shows how the current markets contribute to their development. VFs as well as ecosystem-based food production systems can be a piece in the large puzzle of the food systems and both of the novel technologies are getting traction on the basis of the environmental challenges that are predicted for the near future, which can find conventional agriculture ill-equipped to face. With the understanding of different business models viable for VFs, we can acknowledge that relying solely on selling crops could be unsustainable for new technologies. AMI systems being a conglomerate of different organisms can have sub-optimal growing conditions for each individual crop/organism so the challenge comes in finding the middle ground for all the wide diversity. This comes with lower yields compared to conventional agriculture and current VFs, but it can make up for this on quality aspects. The AMI concept is developed around making value out of waste streams and obtaining revenue by managing inputs and outputs (processing waste). In the economic section, we will discuss more how AMI systems can survive in current markets, as well as what needs to be changed for the future, taking into consideration the most important advantages of lowering environmental impact.

7 THE ROLE OF TECHNOLOGY IN OPTIMISING COMPLEX MULTI-ORGANISM SYSTEMS

Today's state of the art of the ecosystem food production relies on knowledge of each individual crop. As described in the previous chapter, there are a number of possibilities for connecting different organisms in one single growing system. The benefit of this would be that the output of one subsystem, which is currently discarded, contributing to a negative impact on the environment, would be now valued as an input to another subsystem.

7.1 Technology, Data, and Knowledge

When considering conventional VFs, technology plays a big role in the growing process. It can be both the advantage and the challenge, depending on which of the side you position yourself. It can increase the yields and the quality of the products, yet it lowers the biodiversity by streaming the focus on a few candidate crops. What can change this paradigm is data.

The benefits of AMI systems that use waste streams as inputs are obvious. The difficulty lies with the nutrient use efficiency of the whole system. Having multiple loops within the system, the total efficiency is influenced by each individual organism's efficiency (eg. 10% efficiency of waste conversion would lead to 10% efficiency of insect production and so on until the end of the chain). Each pair of subsystems, such as fish and plants, add to the complexity of the food production ecosystem.

The processes between different organisms is better understood by generating more data about many parameters that are relevant in connecting these different organisms. As stated before, there is extensive research on each individual crop, but knowledge is lacking on the interactions between different organisms, and about the relations between them. To improve the knowledge on these innovative food production systems, we have to identify the parameters that are most relevant for each system, such as temperature, pH, humidity, total dissolved solids, etc., and implement data acquisition protocols through sensors or lab tests. The acquired data to optimise the systems for higher efficiency. There are known thresholds for optimal growing performance for each of the organism, but when linked with other systems, one has to understand that compromises must be found to reach the highest productivity for each crop without forcing another one's limits.

To add another layer of complexity, there are different species of the various organisms that can be interlinked in AMI systems. Each individual species has its own set of optimal parameters, so one's experience and validated results may not necessarily overlap with someone else's setup. The diversity of species within an organism genus is important for the design of the systems. Diversity is the key to reaching resilience of the food production system.

This being highlighted, it is important to build sharing platforms for data that acquire information from different AMI farms and use this knowledge in a form of consultancy to optimise farmers' systems and improve their environmental and economic sustainability, as well as improving scientific knowledge on these systems.

7.2 Using Technology to Optimise and Automate AMI Systems

Technology is a tool to acquire data that improves the understanding of the complexity in AMI systems. This improved understanding aids the further development of technology to further optimise these systems. This is a beneficial feedback loop that results in a rapid development of the food production technology whilst improving efficiency, productivity, and bringing systems closer to having a positive impact on the environment. This feedback loop will be further explored in the next chapter, focusing on a case study. However, it is important to highlight the potential of reaching autonomous food-producing systems that are using machine-learning algorithms to ever-improve on all grounds.

There are a few steps in reaching this goal:

1. Acquire big data sets

2. Build models and find trends

3. Validate models

4. Use models as input in the automation system

5. Use machine learning systems based on the models with specific goals

6. Start from step 1 for further improvements

Data acquisition and its importance has already been discussed. The next part is to search for trends in the data and correlations that are meaningful for accurate predictions of productivity and the quality of end-products. Once models are built and validated through systematic experimentation, new information can be fed back into the automation script. The hardware will also be optimised so that the factors that are correlated are also controlled (e.g. the air pump will start based on the dissolved oxygen input and the desired threshold). The improved version of the system now adapts constantly, based on the acquired knowledge. All the farmer needs to do is monitor these processes. Adding machine learning algorithms adds an extra layer of self-improvement of the system based on the newly-acquired information. This leads to even faster development. When new questions arise in the context of production, new tools for getting more relevant data are acquired and the process continues from the first step. The system is improved even further by adding other factors such as the site, market opportunities, available resources, waste streams, and so on. This in turn adds to the resilience of the system.

This approach may seem far-fetched, but it is worth putting the effort on this trajectory for dealing with such complex systems and the multitude of links that could overwhelm human understanding otherwise, postponing the implementation of such ecosystem food production systems. Agriculture is on the path of being digitised. Technology plays an import role in bringing nature back into the food system by mimicking the same process to the benefit of farmers, consumers, and the environment.

8 THE ECONOMIC LAYER OF URBAN ECOSYSTEM FOOD PRODUCTION

When building a controlled-environment food-producing ecosystem - or AMI farm - compromises between the numerous organisms have to be made, as previously discussed. This will result in lower yields for each separate organism compared to conventional systems. The reduction in yield has economic implications, but could be offset by the reduced need for raw materials. This chapter explores the potential and challenges for food-producing ecosystems from an economic perspective.

8.1 Investment and return on investment

The production processes of the different organisms in an AMI farm are very similar to a regular farming operation of a separate species. As a result, the same tools and machines are used. This results in the amount of investment needed for an AMI farm being almost equal to the investment for, say, the three separate species. For example: when combining recirculating aquaculture with hydroponic plant production (aquaponics), the water flow of the separate systems has to be connected and adjusted to each other. This comes down to arranging piping work between the systems, though in both systems piping for the drainage of leach water need to be built anyway. As a result, the investment needed to combine systems is not the biggest hurdle to make an economically-feasible AMI farm.

The challenge comes with the return on investment. Return of investment (ROI) is the ratio between the net profit and the total investment. To maximise ROI, the maximum economic value has to be extracted from the investment. This can be done by maximising revenue and/or minimising costs. In agriculture, maximising profit translates to getting the highest possible yield. To ensure the highest possible yield, all environmental variables are optimised for the specific organism. In an AMI system, compromises have to be made between the different organisms. These compromises can be minimised by selecting the right species, but the compromise will remain nonetheless. This will result in lower yields for the same investment. However, the strong point of every AMI farm is the lower costs of the operation, as waste streams are used as the main input. This is in contrast to a regular farm, where more costly materials are used. Playing to this strength of AMI systems could result in an AMI farm being profitable.

Going back to the aquaponics example, a compromise between the plants and the fish has to be made. Fish thrive in water with as little nutrients as possible. Plants thrive in water with a high concentration of nutrients. A good compromise between plants and fish can be made, but it results in a comparatively lower plant yield per square metre and/or lower fish yield per cubic metre. Whether using aquaponics or artificial nutrient solutions, the investment for a plant factory is roughly the same. However, in aquaponics, running costs are minimised by using the waste water from the fish to feed the plants. This reduces the costs of disposing nutrient-rich water which would need to happen in conventional aquaculture, and saves on external fertiliser costs of a conventional plant factory. This reduces the operational costs of the AMI farm, which could potentially offset the reduced production.

8.2 Production factors

Production factors are all the inputs needed to produce a certain good: land, raw materials, labour, capital, and entrepreneurship. The plant factory part of the aquaponics unit not only has crops as a product, but offers waste-water treatment services, whilst offsetting the need to buy fertiliser. This dual income stream, where production factors like fertiliser are replaced with a service like waste treatment, could be a business model for AMI farms and other circular ventures. In this business model, the company can save on production costs, as raw materials are an income stream as well. In agriculture this is already being practised: for example, dairy farmers pay arable farmers to take their manure. An aquaponics system is an aquatic version of this combination of livestock and crops, effectively vertically integrating the production chain. This should benefit both operations.

There are many waste streams that have not yet been used to their full potential and could be used to fuel an AMI farm. The producer of the waste stream has to pay for the transport and treatment of it, and often a tax is applicable. In the Netherlands, for example, waste that is incinerated is taxed at 32.12 per tonne. This is done to encourage recycling. Changes in policies like these towards more circular systems could improve the financial feasibility of an AMI farm.

8.3 Conventional cost versus environmental full cost accounting

Taxes on waste treatment to encourage recycling can also be seen as a small implementation of environmental full cost accounting (EFCA). EFCA is a method to include the indirect (environmental) costs of a product. An example of this could be aeroplane travel, which is relatively cheap, but produces high amounts of carbon dioxide. This has high environmental costs, as countries for instance have to build infrastructure to counteract rising sea levels. If these costs were factored into the price of an plane ticket, many airlines would have difficulties in sustaining a rapid economical growth. This principle of EFCA can also be used in agriculture. When this is done, AMI systems could be more economically viable, since the use of waste streams instead of virgin materials should have a lower impact on the environment. A sort of EFCA is also a law imposed by a government that forbids the disposing of certain compounds in the environment. For instance, intensive production of pork produces ammonia. In the

Paris. Urban orchard. I. de Felipe

Netherlands, an ammonia scrubber has to be installed in pig barns [1]. This is an expense to the farmer, as it has high investment- and running costs. However, the same result, namely scrubbing air of ammonia, could also be achieved using algae. Algae take up ammonia and carbon dioxide, whilst producing valuable fatty acids. As a result, when algae are coupled to pig-rearing, the principles of ecosystems are applied and an AMI farm is created. This may alleviate some of the farmer's problems, whilst creating an extra income stream.

8.4 Community Supported Farming

One of the big drivers of all current food production systems is that the laws of supply and demand reflect the current market dynamics. This is detrimental for the quality of food and the quality of the environment. As a response to this phenomenon, food cooperatives and community supported agriculture (CSA) have been growing trends in the food scene. In these types of organisations, a community of people who value health and the environment find aternatives and grow food in a sustainable way. This is described by the Peer-to-Peer Foundation as "commons", an old concept which is seeing new light.

As AMI systems have still not yet been proven to be competitive with conventional agriculture, in the current market types, organising community supported AMI systems could well be a feasible way to kick-start many of them. In this way, the community pays for the upcycling of waste, food production, and research to improve food production systems.

9 CASE STUDY: PLANTGEEK PROJECT

Plantgeek is a research group based in Romania at the University of Agricultural Sciences and Veterinary Medicine, in Cluj-Napoca, funded by the German Environmental Foundation and coordinated by the University of Applied Sciences in Neubrandenburg in Germany. Its research is focused on aquaponic systems and combines the knowledge of plant production with available technology in order to improve food production. The aim of the research project is to use affordable sensors and platforms for automation in order to test the limits and robustness of the system with cheap infrastructure and to get large amounts of data from as many sources as possible for a better understanding of the indoor ecosystems and how the plants are influenced by the environmental factors.

9.1 System description

The research project was conducted at the University of Agricultural Sciences and Veterinary Medicine in Cluj-Napoca, Romania in the Institute of Life Sciences. The laboratory was established in the basement of the institute in order to minimise influence from the outer environment. The aeration and climate control were done with a mobile air-conditioning system linked to the central ventilation system.

The system consists of four water tanks (three of 500 litres and the one of 300 litres) and two vertically-stacked plant trays (around 150 litres, 3 metres long, with an adjustable water level). The irrigation system was made with 25-inch pipes linked to the pumps in the system. LEDs are installed above each tray with a self-built system that allows the controlling of the light intensity by adjusting the height from the plants. All components that went into building the system were acquired locally.

The nutrient flow is described in Fig.4, and is as follows. From the fish tank (2), water is pumped through a swirl filter that separates the solids, to the biological filter with nitrifying bacteria (3). Then, the water is pumped to the two plant trays (4), from where it gravitationally flows in the drainage (5), from where the water is pumped back to the fish tank through a ultraviolet filter. The water flow is automated based on water level sensors. Furthermore, water parameters such as pH, electrical conductivity (EC), dissolved oxygen (DO), temperature, and environmental parameters such as temperature, humidity,

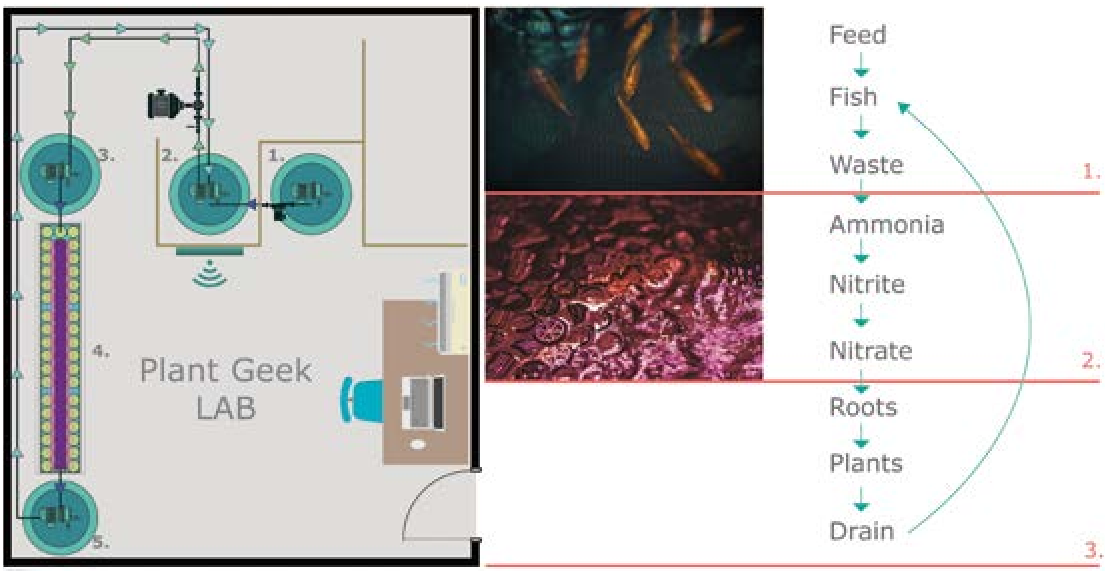


Figure 4: The layout of the lab. 1 sump tank, 2. fish tank, 3. nitrification bioreactor, 4. plant trays, 5. drainage tank

and light intensity are monitored through the sensor system in each tank and tray. This data is complemented by weekly measurements of the plants (biometric data and chemical analysis), fish (size and weight), and lab analysis of the nutrient solution (nitrite and nitrate levels).

The objectives of this research project are to analyse how the automation and a big sensor network help the team to better understand the processes happening in the artificial ecosystem. There were four iterations before the team got to the optimal fish/plant growing protocols. In this time, rsearchers have grown goldfish, carp, and African catfish in symbiosis with spinach, lettuce and basil respectively.

To achieve the goals of the research project, various low-cost sensors and platforms were used, to make sure the system was affordable and easily replicated. Therefore Raspberry Pi, Arduino, and Windows platforms were used.

9.2 Automation and Data Collection

In order to fulfil the project requirements of using low-cost equipment, it was decided to use some of the most important parameters for an aquaponic system. The sensors used in the research project are listed in the table below.

The automation of the aquaponic system is achieved by recirculating the water from one tank to another, based on the reading from the wireless water level sensors. For an optimal water flow, three water cycle phases were devised: 1. from the fish tank to the bacteria tank 2. from the bacteria tank to the drainage tank, trough the plant trays 3. from the drainage tank back to the fish tank). Two of the water level sensors were placed on each tank to signal the minimum and maximum water level. Based on these readings, the system either starts or stops the water flow.

The sensors placed in each water tank or plant tray gave a real-time view of the required parameters from the system, as presented in Fig. 5. The sensor readings can be viewed as a graph and are compared with readings from other sensors. If the sensor values are out of their corresponding thresholds, an alarm is triggered, and the associated value turns red.

9.3 Results

During the research trials different growing media, plants and fish were tested to see which combination better serves the research goals.

The growing media that was tested for seedling production were soil and rockwool. Of these two, the latter was chosen, due to the difficulties that were faced with the

Table 6: An overview of the main sensors used in the system

Name	Quantity	Location
Water level sensor	8	Water tanks 1,2,3,4,5
Dissolved oxygen sensor	4	Water tanks 2,3,4,5
pH/EC sensors	5	Water tanks 2,3,4,5 and in both plant trays
Light sensors	4	Both plant trays
Water temperature sensors	4	Water tanks 2,3,4,5
Air humidity and temperature sensors	6	Both plant trays and placed in the lab

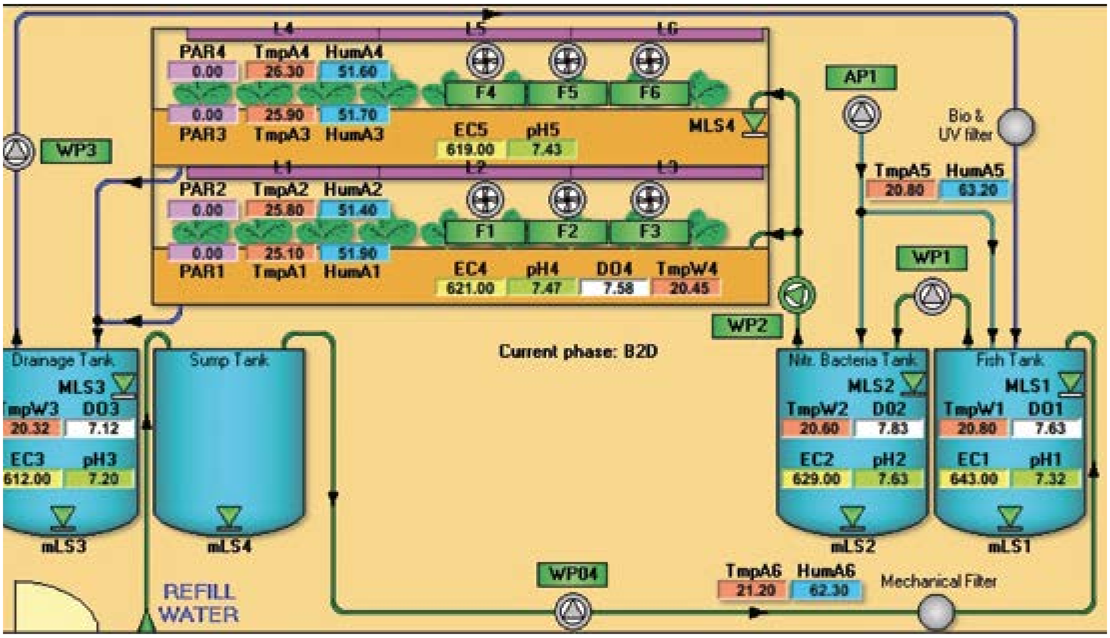


Figure 5: Sensor system interface for monitoring and data collection

transplantation from soil to the hydroponic trays in regard to cleaning the soil out of the roots. During this process, the frail plant roots were often damaged. Thus, using rockwool, the substrate with its seedling could have been directly transplanted in the system.

The first plant species used was spinach (*Spinacia oleracea*), but due to the difficulties in transplantation and plant development, the switch was made to the basil (*Ocilum basilicum*). The candidate plants had to have a short vegetation period and to be interesting not just for the development features, but also for the bioactive compounds. Spinach proved to be a difficult plant to grow in the system. After a few weeks of experimenting with it, the trials were stopped. Basil turned out to be a better suited plant, as it seemed very resilient and its development from seed to harvest was relatively short, allowing multiple research trials to be done. For each research trial, about 300 plants were planted - 150 for each tray. Weekly morphological measurements were conducted on parameters such as stem length, leaf number, area, internode length, root length, and chlorophyll content (SPAD value). For the plant quality, parameters such as vitamin C, flavonoids, and beta-carotenoids content were tested on a weekly basis using HPLC (High performance liquid chromatography) equipment.

As for the fish species , the goldfish (*Carassius auratus*) was the first choice. This turned out to be a difficult choice for the research purposes, due to their slow growth. Therefore, for the second trials, carp (*Cyprinus carpio*) was used, because nutrient solution data has shown that the system needed a higher fish biomass for higher nutrient production. The feeding regime was based on the rule of thumb in aquaponics that says that feed rate should be around 3% of the total fish biomass. As a result, weekly feed rate was adjusted. The carp, however, needed a long time to adapt in the system and proved to have an unstable feeding behaviour, which resulted in an excess of food being dissolved in the water. This food excess led to a decrease in water quality, due to the increase levels of ammonia and nitrite which is toxic for the fish. They also showed stress under low pH that occured due to the nitrification process.

Having difficulties with the first two fish species, it was decided to use a more resilient one. As a result, the African catfish (*Clarias gariepinus*) was chosen. This third trial proved to be a better choice, due to the fact that the African catfish tolerates lower dissolved oxygen by developing lungs at maturity, and adapts well to fluctuating pH levels. This also proves that the diversity of species that could be implemented in AMI systems plays for the advantage of the farmer, in the sense that it is a more resilient approach to choose suitable species than to be involved in changing environmental parameters. Furthermore, they responded better to the feeding regime, meaning that they offered more predictable and stable results for the research project.

The fish were measured on a weekly basis to determine their growth rate, but also to determine the food quantity needed for their respective weight. For this purpose, 30 random fish were selected and measured (weight and length). Following the 3% rule, the weekly feed rate was adjusted with the help of an automatic feeder. If the fish were not eating the whole food, adjustments were made accordingly.

The most important factors in the AMI system are related to nutrient flows and in aquaponics, especially the water quality parameters. In this category, two methods of data gathering were used. The first method was conducted with the help of sensors connected to the system. Therefore, data regarding pH, electrical conductivity (EC), total dissolved solids, dissolved oxygen and temperature were taken. The second method was done by collecting weekly water probes from each water tank to determine the nitrite and nitrate levels, which were then analysed with specific laboratory equipment (spectrometry).

One of the challenges regarding the water quality was ensuring the right parameters for all the organisms present in the indoor ecosystem. The pH level, as an example, for optimal plant development need to be between 5.5 and 6.5, but for the nitrifying bacteria to work properly, the optimal range is around 8, and for the fish, a pH value close to 7 was needed. This represented a conundrum. Such difficulties needed to be addressed. The project aimed to use the data for better understanding the process between the different organism, therefore the team did not intervene chemically in adjusting the pH.

Other parameters, such as dissolved oxygen are equally important as the pH, for an effective system. An air pump was used to improve aeration for the bacteria and the fish tanks. The pumps that determine the hydraulic load rate (HLR = m^3 volume of water/m^2 surface/day) are also influencing both the oxygen saturation of the water and the nitrification process. The flow was quite short, from 10 to 40 minutes which did not allow for the oxygen to get depleted quickly in the system. The measurements showed the dissolved oxygen was constantly over 7 mg/L, which is optimal for all the organism, with just lower thresholds in the plant trays, which is optimal for nutrient uptake rate.

Having to deal with such a complex system showed how much data its needed for making sense of the convoluted interaction between the organisms. The most interesting results were around the nitrification/denitrification processes that are at the core of the system efficiency. The most important lesson from this project was that no organism can be prioritised in the ecosystem. Having more feeding input with the catfish seemed optimistic for the nitrate production for the plants. But it was surprising to see that the nitrate levels were not significant higher than the ones obtained with the carp. This fact showed that the bioreactor reached a limitation so the heterotrophic bacteria might have won in the competition with the nitrifying bacteria. This type of information can help in planning and designing the AMI systems and it is important to encourage more farmers and scholars to share experience and data for advancing knowledge in the ecosystem food production.

9.4 Next steps

The next steps of the research project are open to more interesting question as the possibilities are plentifully. For the next few months, the work will continue on the current setup by testing bigger variety of leafy greens, while improving the fish feeding cycle. Regarding feed, one of the mid-term goals, is to develop an autonomous fish-feeding device. This device will be able to feed the fish based on images of the leftovers. Based on the results collected and with the help of machine learning, the device will self-regulate, increasing or decreasing the amount of feed. The images turned into quantifiable data will also be of great aid to understanding the processes in the aquaponics from the feed to the bioreactor, all the way to plants.

Another midterm next step for the research is to integrate in the already-working ecosystem another piece of the puzzle. The options can be adding insects for feeding the fish, or by growing mushrooms on the plant unedible mass, thus closing one more loop in the system.

Until reaching the mid-term goals, on a shorter time span, the focus is on on optimising the sensors/automation system, so that the collected data can become more reliable. Also hardware is prone to improvement as we have seen that the types of pumps, tanks and pipes can influence important factors in the system. Using the data gathered until now, we will look for correlations and trends that can be used as inputs in the automation script. We will build models and validate them with the next experiments and get closer to the autonomous indoor ecosystems.

10 ACKNOWLEDGEMENTS

The authors would like to acknowledge DBU (German Federal Environmental Foundation) for funding the Plantgeek research project (Project No. FKZ DBU: 33716/01-35)

11 REFFERENCES

[1] BACKES, C. W., ANKER, H. T., KEESSEN, A. M., BAANER, L., & MÖCKEL, S. (2018). "Comparison of ammonia regulation in Germany, the Netherlands and Denmark-legal framework." IFRO Report series.

[2] BOMMARCO, R., VICO, G., & HALLIN, S. (2018). "Exploiting ecosystem services in agriculture for increased food security." Global food security, Volume 17, Pages 57-63.

[3] EDENBRANDT, A. K., GAMBORG, C., & THORSEN, B. J. (2018). "Consumers' Preferences for Bread: Transgenic, Cisgenic, Organic or Pesticide- free?." Journal of Agricultural Economics, Volume 69 Number 1, Pages 121-141.

[4] ERICKSON, M. C., ISLAM, M., SHEPPARD, C., LIAO, J., & DOYLE, M. P. (2004). "Reduction of Escherichia coli O157: H7 and Salmonella enterica serovar enteritidis in chicken manure by larvae of the black soldier fly." Journal of Food Protection, Volume 67 Number 4, Pages 685-690.

[5] GOPALAKANNAN, A., & ARUL, V. (2006). "Immunomodulatory effects of dietary intake of chitin, chitosan and levamisole on the immune system of Cyprinus carpio and control of Aeromonas hydrophila infection in ponds." Aquaculture, Volume 255, Number 1-4, Pages 179-187.

[6] VAN DER SPIEGEL, M., NOORDAM, M. Y., & VAN DER FELS-KLERX, H. J. (2013). "Safety of novel protein sources (insects, microalgae, seaweed, duckweed, and rapeseed) and legislative aspects for their application in food and feed production." Comprehensive Reviews in Food Science and Food Safety, Volume 12 Number 6, Pages 662-678.


FEDERACION DE ENTIDADES
EMPRESARIALES PRIVADAS DE
COCHABAMBA

Vertical garden in the Federation of Private Businessmen of Cochabamba. Bolivia. Paisajismo Urbano

CHAPTER 8

VERTICAL ECOSYSTEMS: THE VALUE OF FIELDWORK

Ignacio Solano
Head director of Paisajismo Urbano

SUMMARY

As cities face an increase in urban density and scarcity of surface space, garden facades are an alternative that provide multiple benefits to the urban ecosystem. These vertical gardens improve air quality and acoustic conditions, while regulating the temperature in the urban environment and providing aesthetic value to cities.

A requirement to convert a vertical garden into an authentic urban ecosystem lies in the combination of native plants, with animals that are interested in them. With this interaction, a botanical and biological value is added to the project. The importance of working with a native plant justifies the realization of fieldwork in areas of similar climate to the place where the green wall will be later constructed.

These actions require thorough planning and are not exempt from risks or logistical difficulties; However, the botanical value that these native species provide can be the difference between a lifeless vertical garden and a sanctuary for a certain species of animal.

KEY WORDS

Vertical garden, native species, botanic expedition, exotic plants, vertical ecosystems, fieldwork.

1. INTRODUCTION

Progress, understood as an improvement of human condition, emerged thanks to the industrialization and technological innovation that has fostered economic and social development. However, these advances cannot translate into an improvement of our quality of life, since they have brought with them environmental problems, pollution and climate change, which cause diseases and millions of deaths every year. (WHO/OMS, 2014).

Polypodiaceae growing in vertical conditions in the Bolivian Chaparé forest.

Monstera oblique growing in low light conditions in tropical understory

Frequently, the population is not aware of the seriousness of these environmental problems. According to the latest CIS barometer, from December 2018, the percentage of Spaniards who consider environmental problems as the main problem in Spain, is only 0.1%. Those who value it as the second most serious issue represent 0.2%, while 0.5% consider it the third most serious problem in our country (http://www.cis.es). This lack of awareness has, in part, much to do with misinformation, and even to do with some politicians or administrations making the topic somewhat trivial.

Fortunately, there are more and more individual actions in response to these problems, that mainly affect the most populated cities, where conurbation has destroyed the natural vegetation. The development of vertical gardens is one of the solutions that exist to counteract pollution in cities and provide a healthier environment for citizens. However, the benefits go far beyond trying to reduce pollution. It is about recreating an ecosystem where humans, plants and animals live in harmony without giving up the beautiful and natural environment.

2. THE USE OF NATIVE PLANTS IN VERTICAL GARDENS

From the first moment that a vertical garden is made a project, it is necessary to understand the soon-to-be green wall as an integral part of the human ecosystem. Since the beginning of time, human beings have lived in harmony with nature. This has changed radically since the Industrial Revolution, which forced us to leave the field and establish ourselves in a hostile environment for which we were not designed. This new way of living, in cities far from nature, has caused conflicts in addition to a great spiritual and existential vacuum.

A solution to these problems is to return to the past, integrating nature in our societies, through the design of artificial ecosystems, in which both plants and animals have their space. Plants are necessary for life, thanks to their oxygen production work. Moreover, it is known by all, that in cities plants help to counteract the "urban heat island" effect, which is caused by the excessive construction of its surroundings. However, the ecosystem would be incomplete if those plants were not related to the urban fauna.

In any ecosystem there are always animals. In our human ecosystem there are birds that feed on the detritus that we leave, rats which are responsible for processing waste and pollinating insects that are necessary for life, because they pollinate the plants that later serve as food. One of the objectives when creating a vertical ecosystem (Ignacio Solano, 2011) is to bring back the urban fauna which provides a biological value and, to achieve this, the use of native plants that arouse an interest for these native animals is crucial.

For many years, burnt forests have been repopulated with exotic plants, such as eucalyptus, a plant that evolves in its own ecosystem, in the forests of Australia. There it serves as food for animals such as koalas, and for pollinators who are specialised in it. In other countries there is no such fauna specialised in these plants, so repopulating the forests with these exotic species leads to sterile forests, in which the interactions between plants and animals do not occur.

Another example of the introduction of exotic vegetation, which does not generate an interaction between flora and fauna, occurs in the Mediterranean Sea with the alga Caulerpa taxifolia. This species was accidentally introduced in 1984 by the Oceanographic Museum of Monaco, apparently after the emptying of one of the museum's aquariums. (https://waste.ideal.es/alga.html). The temperature of the Mediterranean water favors the invasive growth of this seaweed, which has been displacing the endemic Mediterranean species, the aquatic plant, Posidonia. In addition, Caulerpa taxifolia is a toxic species for fish which are native to the Mediterranean Sea, which causes an invasion of plant meadows that do not serve as food for any animal; they are green deserts where there is no life. In the tropical waters of the Philippines and the China Sea, where this species is native, there are fish that have evolved with that plant and benefit from it, but outside its natural environment, it only causes damage.

Detail of lithophyte ferns in tropical understory in the Selva de Misiones in Argentina

Peperomia spp. growing epiphytically on branches in scarce light conditions in tropical understory. Costa Rica

Begonia spp. growing in tropical understory of eastern Ecuador only with an amount of light of 300 lux

The incorporation of native plants in the construction of a vertical garden also provides an added botanical value. It must be taken into account that in Spain, most of the plant species that are located in public places are exotic plants. For example, it is believed that the date palm (Phoenix *dactylifera*) comes from North Africa (Zeven & de Wet, 1993) or from the area between the Middle East and Kurdistan (Zohary & Hopf, 2000). Another example of an exotic plant that has been introduced as an ornamental species in Spain is Ficus *benjamina*, which comes from the south and southeast of Asia, and from the south and north of Australia.

This tendency of incorporating exotic species is closely linked to the Victorian era, that established the presumption that wild plants, which are born naturally thanks to the propagation of seeds, have no value, when in reality it is the opposite. For a vertical garden to become an authentic vertical ecosystem (Ignacio Solano, 2011), the introduction of a native plant is mandatory.

3. FROM VERTICAL GARDEN TO VERTICAL ECOSYSTEM

Once the importance of using a native plant for the construction of a vertical ecosystem is justified, we must know which plant families are the most suitable, depending on the climatic conditions of the place where we are going to carry out the project. When selecting the different species, it is convenient to look for plants that provide added value. Currently, of the 35,000 plants used by humans, some 28,000 are for ornamental use. (José Manuel Sánchez, 2012)

The tendency to work with a native plant is increasing in vertical gardens located outdoors. However, when it comes to indoors,

Ignacio Solano examining lithophyte plants from the Mexican deserts of Veracruz

the adaptive limitations of these plants force us to work with tropical species in many cases, since the so-called "indoor plant" does not exist as such. It is nothing more than a plant that evolved in poor light conditions. Although it is true that in areas of warm climate we can work with a native plant, when we work on interior vertical gardens it is difficult to find a native plant that can satisfy our needs, because it needs cool periods rather than the more average temperatures of indoors.

There are two factors that guide us when it comes to working with tropical plants. The first is that they are understory plants, with which any understory would provide us with the species we need. The second and decisive factor is that they are plants that need mild temperatures so, in most cases, they will be plants that have grown in tropical understory, such as Pteridophyta, Araceae, Arecaceae, Driopteridaceae, Peperomiaceae or Pteridaceae.

The selection of species for the realization of the outdoor vertical garden will depend on which predominant species are in the zone of work. In the event that we were going to begin a vertical garden project in an area with a Mediterranean climate, we would choose to select some species of Lamiaceae, Bignoniaceae, Crasuláceas, Rosaceas, Berberidaceae and Juncaceas. If the work zone had a cooler climate, the tendency would be to work with families of Cupresáceas, Oleáceas, Brasicáceas or Cistáceas.

The advantage of working with these large plant families, for outdoor vertical gardens, is that we know that these families work. For example, within the family of the Moraceae, different genera and species can be used in Spain and Argentina. Amongst the native species that live in Argentina, we will find Moraceae which will work well, just as in Spain we will find other species of Moraceae that will also work. As these plant families live throughout the continent, we can use the genera that have developed in those climates in which we are going to work.

In my vertical ecosystem projects, I always try to introduce these native species, but also some endemic species from the place where the garden will be constructed. That is why I follow a certain selection process. For example, if we were in Argentina, where we work with species of Moraceae, we would look for a rarity within that species in that ecosystem; in other words, we would use the endemic Moraceae of that zone of Argentina to contribute to the project and provide that added value of botanical interest.

Regarding the importance in the selection of species, our experience provides us with a starting point. Therefore, once proven that all these families work in the construction of the ecosystem, it is much easier to later spend time trying new combinations.

4. THE IMPORTANCE OF FIELDWORK BEFORE A VERTICAL ECOSYSTEM PROJECT

The growing demand for indoor vertical gardening projects, or outdoors in tropical areas, justifies that a great portion of our interest is in tropical forests. In an ecosystem as complex as a tropical forest seldom or hardly ever are there problematic pests. This is because there is such a biodiversity that there are phenomena called positive allelopathies and negative allelopathies. Positive allelopathy is a collaboration between plants, which favors the growth between plants, which for example occurs between some species of fabaceae and other plants.

The Aztecs had already discovered these benefits by planting corn next to beans. They observed that corn grew much faster when partnered with a legume plant. Legumes, like beans, have nodules in the roots where bacteria inhabit and is responsible for taking the nitrogen in the atmosphere and mixing it into the soil. With this interaction, the beans fertilize the soil and in turn benefit the corn. In addition, since the bean is a climbing plant, it uses corn as a support, which is why this positive allelopathy generates a symbiosis between the two species.

Another example of allelopathy occurs in the case of a plant that may be the antagonist of a pest to which another species is susceptible. This happens, for example, with Peppermint, a plant that is susceptible to the insect Trialeurodes spp (Hemiptera: Aleyrodidae), commonly known as whitefly. The violet Tulbaghia plant is a potent repellent for this pest, therefore, with this information, if at the time of creating a vertical garden we placed these two species together, there would be a phenomenon of positive allelopathy; a perfect combination where one plant will be protecting another.

We know that these allelopathic relationships exist in forests. Here lies the importance of carrying out fieldwork before the completion of the vertical project. We must bear in mind that these gardens involve a very high quantity of plants, which we will have to condense into the smallest possible space, so it is very important to select the species that coexist the best and which allow these symbiotic relationships. There is hardly any documentation on this allelopathic phenomenon in the ornamental plant, although some information can be found in the Permaculture treatises.

Thanks to previous fieldwork we can explore areas that have the same climate as the place where we will install our vertical garden and look for the species which have that botanical value that may interest us, or that have an attractive power for certain species of animals.

An example of this attractiveness, thanks to the use of native species, is our vertical garden of the Santalaia building in Bogotá. We discovered that in the city of Bogotá there was a hummingbird that was endagered, the Amazilia tzacatl. In a megacity like Bogotá,

Adult specimen of the very common Bothrops Asper in the jungle of the Colombian Chocó. Ignacio Solano

this bird is very exposed, since it flies from plant pot to plant pot, so we decided to turn the vertical garden itself into a sanctuary for these birds. Thanks to the principle of positive and negative allelopathies, my vertical gardening projects do not require the use of phytosanitary products; therefore, these small animals are now more protected thanks to the plant facade.

One of the plant families that this hummingbird feeds is one of the varieties of native Lamiaceae. After conducting our fieldwork in the nearby forests, we discovered what species of this plant family were in the area, and in turn we found some commercial plants which also possessed this attractive power. Taking into account that a plant facade requires a high quantity of plants, the tendency is to introduce as many native species as possible, although the bulk of the garden will inevitably be formed by a commercial plant. Within that commercial plant we will look for the one that also includes all of these factors.

5. IMPLEMENTATION IN PROJECTS

A project of such extensive proportions as the vertical garden of the Santalaia building in Bogotá requires equally thorough planning. In the case of this Colombian garden, planning had to be done three years in advance. When the moment arrived for the project to become reality, with the help of our Colombian partners, we decided that it was a building that had enough botanical value to justify an expedition in search of a native plant that could be of interest.

Unfortunately, we could not make use of all the native plants we had discovered, due to a matter of agenda and time. The garden of the Santalaia building is currently the largest in the world, with 3,116 square metres of facade with more than 100,000 plants. Propagating this amount of native species would be economically unfeasible, besides requiring the creation of an entire infrastructure to reproduce such a variety of plants necessary for the project.

70% of current plant coverings continue being created with plants of common ornamental use, although the intention is to increase the percentage of native plants used in vertical gardens. Our first projects had 2% of native or endemic plants, while we currently use up to 30% of these species. We understand that these projects should be done like this, even though the infrastructure that is required does not provide an immediate economic return. True to our commitment to the environment, we understand that the success of the project is not only measured by the economic return, but by the significance of the project itself and the benefits it produces on other levels.

6. FIELDWORK AND EXPEDITIONS

Carrying out a botanical expedition requires multiple preparations and extensive documentation prior to the expedition. We enjoy doing fieldwork while seeking funding, knowing that it is difficult for a company to pay for something that will not gain an immediate economic return. In addition, an expedition of this type is a great investment; not only because you have to have a team consisting of five or six people, but also to document absolutely everything, in addition to having recording material and other survival and climbing equipment.

Fieldwork gives us access to different ecosystems that may interest us, since we work a lot with the altitudinal gradient. The same geographic area offers us from humid deciduous tropical forest at sea level, to temperate humid tropical forest at 500 metres of altitude, passing through mesophilic tropical forest, located onwards of 1000 metres, to montane forests located at more than 1800 metres of altitude. This altitudinal stratification provides us with diverse ecosystems where

Ignacio Solano selecting samples of tropical understory plants. Jungle of the Darién. Panamá

Ignacio Solano carrying out an examination of epiphytic plants in the Colombian Chocó jungle

we can research and select plants without the need to travel a large number of kilometres.

Another factor that influences the plant species within the same area is the orientation of the mountain. The vegetation is not the same on a mountain that is leeward than in one that is windward, just as the north face has completely different vegetation to the south face. Exposure to the winds also influences the vegetation. There are different factors that we have to take into account when looking for plants. For example, a ridge is not the same as a stream. In a ravine or gorge, where a river often flows, it is usually very hot and humid, so the vegetation is very different from that found on a ridge.

Most of the plants that we use in our vertical ecosystems are lithophytes, that is, they live on stones in vertical conditions. To access these walls, it is necessary to have a specific material that allows rappelling or climbing, as well as mastering the rope techniques to access these locations. It is a matter of passion for what we do, since we are amateur cavers, climbers and biologists.

Once the species that interest us are located, and with the corresponding permission, we take a small sample at a cellular level, disinfect it in a solution and keep it for later treatment with hormones and in vitro propagation. This is a very minor invasive technique, since simply with a leaf or with an apical tip, hundreds of individuals can be reproduced in a simple way.

The last expedition that we carried out was to the jungle of Panama, where we discovered some types of philodendrons, barely used in the ornamental market, such as Philodendron *verrucosum*, some types of marcgravia, such as Marcgravia *rectifolia* and some types of vriesea, that we will surely use in future vertical ecosystem projects.

7. DIFFICULTIES DURING FIELDWORK

Fieldwork sometimes involves entering areas where human presence is minimal. In the case of humid tropical forests, with thick vegetation, it is important to use GPS tracking techniques to avoid one of the main problems, such as getting lost in the jungle. In addition, it is convenient to learn from the local guides how the routes are laid out, in order to follow the work transects. The technique consists of always walking in the same direction and knotting a small strip of biodegradable fabric every three or four trees. This technique is like leaving bread crumbs, and combined with the GPS method, it is the most practical and safest way to navigate through the forest to take the plant samples.

Another main drawback has to do with the fauna that we find on these expeditions. Insect bites are very common and annoying, so it is necessary to wear long trousers and long-sleeved shirts, in addition to boots. This is also important to protect yourself from snakes.

In the American tropical forests one of the most significant risks is a snake called Bothrops spp, the snake that causes the most accidents throughout the continent. They are very common and practically invisible specimens since they have a tremendous mimicry with their environment. In addition, they are Viperidae, they hunt by waiting patiently and remain immobile, so it is possible to be less than 50 centimeters from one and not be able to see it, even if you are looking in the right direction. These snakes are not aggressive, but the greatest danger is that they can be stepped on; making protective footwear of vital importance.

Our experience on expeditions has lead us to always include a herpetologist on our trips, an expert on snakes, and even I myself have ended up specialising in these ophidians and being able to recognise them all, which is an added advantage to avoid an accident.

8. PLANT ARRANGEMENT IN VERTICAL GARDENS AND IRRIGATION SYSTEM

The correct functioning of a vertical garden depends on several factors that must be taken into account. These types of walls work with physical, chemical, luminous and hygrometric gradients. Within nature those plants have adaptive capabilities. Depending on the type of plant, it will go in one place or another of the wall, that is to say, on the same wall we can use the upper part for crassulacean plants, succulent plants or semi cacti, that need very little humidity. However, plants that live in puddles of water, such as species from the Junaceae family, will be on the lower part of the wall.

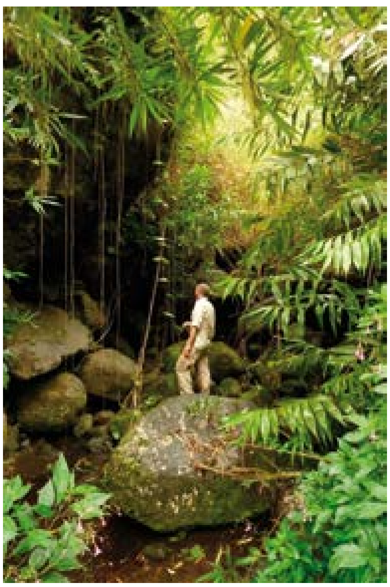
This is because the top part of the wall is permanently dehydrated while the bottom part is permanently waterlogged. This provides a versatility that allows us to use almost any species within the system, taking into account that each plant has a specific place according to their needs. It is important to understand where each species goes in terms of its adaptive evolution and its moisture or light needs. For example, just because Salvia microphylla works well on a certain part of the wall does not mean it will be successful on another part. It can work in one part of the garden and die elsewhere.

A vertical ecosystem that is done properly does not entail an excessive consumption of water, since the garden itself can become a biofilter for all of the excess water of the building. Many of my projects use systems that recover the water from the showers and the cisterns of the buildings themselves, filter them, thanks to the nitrogen cycle, and reuse them to water the gardens. The irrigation system can use different methods, with more or less technology. This will depend on the size of the project. There are many possibilities that can be done, from the very simple, which are not equipped with advanced technology, to truly automated systems that are fully controlled by computer, with water filtration, purification of the gray water of the building itself, the possibility to reuse water from rain, etc.

A healthy vertical garden is loaded with a series of aerobic bacteria, which are called Nitrosomona and Nitrospira. These decompose the ammonium into nitrites and the nitrites into nitrates, thus using the nitrogen cycle so the water comes out clean again. This system has some technology behind it, which includes some bacteria reactors and some fertilizer injectors. We use a hydroponic system when faced with big projects, which is based on the principle that plants do not need land to live, they need something that provides them support for the roots and a substrate that provides them with the moisture and nutrition the plants need. In this case, moisture and nutrition is provided through irrigation with an ultralight mechanical support, made with recycled materials that respect the environment.

It is important to ensure that the wall has the exact chemical composition for the group of plants that we are going to use, as not all species have the same nutritional needs. There are plants that need more of certain salts than others, some that need more acidity than others and ones that need more nitrogen than others. Depending on the group of plants that have been selected, a balanced mixture is prepared that can be used by all the group, based on nitrogen, phosphorus and potassium; This is linked to PH levels that are crucial for the plants adaptiveness.

These hydroponic solutions are designed for each project and ensure that the plants have the perfect nutrition and do not suffer nutritional deficiencies which could cause the plant's leaves to burn or some other small defects. The components of this perfect mixture can be reduced to numbers, so nothing is left to interpretation. If the garden needs a certain amount of nitrogen, phosphorus and potassium, together with the



Ignacio Solano in tropical understory of volcanic soil in Reunion Island. Paisajismo Urbano

Ignacio Solano recognizing plants that grow on the cliffs. Selva de Misiones. Argentina. Paisajismo Urbano

Measurement of the real and non-subjective light of an environment with the use of a luxometer. Paisajismo Urbano

appropriate level of PH, all of this together composes a chemical formula that will have the appropriate properties for the plants.

Throughout the learning process during the past twelve years, in which mistakes have been made, the irrigation systems have been improved. This is something that satisfies me greatly because there are many people learning the process and many competing companies that are seeing that the system works, and copying our work with success. This is an improvement of the system itself and makes us proud to contribute to an environmental recovery.

9. ENVIRONMENTAL AND HEALTH BENEFITS OF VERTICAL ECOSYSTEMS

If vertical ecosystems are done adequately, the list of environmental and health benefits produced by this integration of vegetation in cities is extensive. It has been demonstrated that vertical gardens mitigate the “urban heat island” effect, one of the greatest impacts derived from climate change produced by excessive building in cities. The vegetal facade gives protection from thermal fluctuations and extreme weather conditions, which translates into a decrease in stress in people in hot surroundings, in addition to a reduction in the use of air conditioning. Furthermore, it mitigates suspended particles that pollute the air and pose a risk to health, which results in a more livable environment for citizens. The combination of all these benefits lowers the cost associated with the healthcare of citizens.

Another factor to take into account is the energy saving for buildings, with the consequent reduction of greenhouse gas emissions. This, in turn, prevents the formation of smog that is caused by the combination of nitrogen oxide, which comes largely from the exhaust pipes of vehicles, and volatile organic compounds.

The installation of vertical gardens in cities not only provides benefits for the environment and health, but also offers aesthetic improvements that provide new recreational opportunities for artistic expression or bird watching. The vegetal cover also entails an attenuation of the noise that penetrates the building, that is replaced by naturally satisfying sounds, which contribute to a revaluation of the property.

Spain's largest indoor vertical garden located in a multinational company in Alicante. Paisajismo Urbano

10. BIBLIOGRAPHIC REFERENCES

Briz, J.; Köhler, M.; De Felipe, I. (2015). Green cities in the world. Second edition. Editorial Agrícola. Madrid.

Calle, M.S; Gómez, J.E. LA PESTE VERDE, algas asesinas. Waste Magazine. From https://waste.ideal.es/alga.html

CIS-Centro de investigaciones sociológicas (2018). Barómetro de diciembre de 2018. http://www.cis.es/cis/export/sites/default/-Archivos/Marginales/3220_3239/3234/es3234mar.pdf

Magnini, E.; Schemel, S. Proyecto Madrid + Natural. Adaptación al Cambio Climático basado en la naturaleza. Ayuntamiento de Madrid.

OMS-Organización Mundial de la Salud (2014). 7 millones de muertes cada año debidas a la contaminación atmosférica.

https://www.who.int/mediacentre/news/releases/2014/air-pollution/es/

Sanchez, J.M. (2012) «Nuevas plantas ornamentales» VIII Jornadas Técnicas. Producción y Comercialización de Plantas Ornamentales.

Solano I (2016) La guía definitiva del jardín vertical. Editorial Círculo Rojo.

Zeven, A.C.; De Wet, J. (1993) Dictionary of cultivated plants and their regions of diversity. International Book Distributors, Dehradun.

Zohary, D.; Hopf, M. (2000) Domestication of plants in the Old World. 3ª edition. Oxford University Press. Oxford.

CHAPTER 9

LESSONS LEARNED IN GREEN INFRASTRUCTURE SUCH AS LIVING WALLS, BOTH INTERIOR AND EXTERIOR

Andreas Schmidt (A2)
Founder and Creative Director of indoorlandscaping in Trier, Germany (1998-)
a2@indoorlandscaping.com

Yaël Ehrenberg
Co-Founder of trespuntos (...) and verde360° in CDMX, México (2007-)
yaelehrenberg@gmail.com

SUMMARY

Our living wall stories. A long-term collaboration. Long-term experience.

KEYWORDS

indoorlandscaping, living walls, pioneers, design, sustainability, functionality, maintenance, new generation, purpose, green mission, passion

1. THE GERMAN EXPERIENCE

Andreas' background with indoorlandscaping

As a starting point let me quote a press-release from Architecture Today's EcoTech dated November 2007. That describes our former approach as a pioneer in the living wall industry perfectly —

New developments

A second generation of green walls, pioneered by Patrick Blanc in France, indoorlandscaping in Germany and others, does not rely on climbing plants rooted in soil but on a carpet of smaller plants root¬ed on the vertical surface itself. There are several proprietary systems available and others can be devised from basic princi¬ples. These walls typically comprise a metal frame or mesh, with waterproof backing and felt or another growing medium in which the plants are rooted and watered with mechanical irrigation equipment.

indoorlandscaping is careful to describe its Grüne Wand product as a green wall rather than a vertical garden, a subtle dif¬ference that points to its intended use as an integral architectural element rather than applied decoration. The product was developed after the practice developed a planted wall for Siemens Design & Messe (in 2000) using the customary rolled sod, cultivated on mats for weeks beforehand. indoorlandscaping was unhappy with the weight and durability of the wall, and set about producing an alternative.

Grüne Wand is available in both fixed and mobile forms (for exhibition stands and so on) and comprises a reservoir, pump and planting panels incorporating a polystyrene base plate, a synthetic growing medium of fully hardened phenolic resin and the actual vegetation. The wall has a controllable humidifying effect on the ambient air. In recent years there has been growing interest in using plants not just as a skin but as structural components. At its simplest this might include the use of plants to stabilize embankments, for example, but research continues into the possibility of organic, living structures.

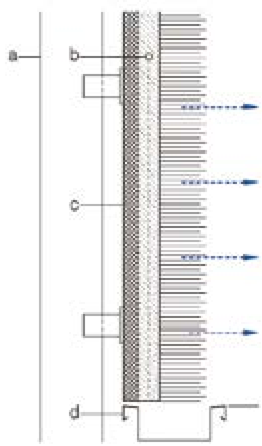
'Our focus as designers is to have a monochrome and graphic, living wall texture'

— Andreas Schmidt

That's a quote in an article of MARK MAG issue #13, released in April 2008 by Frame Publishers. Furthermore I quote a featured article from DETAIL issue 12/2008 published by Frank Kaltenbach, the first important journalistic review of living walls back then including a technical comparison of the available systems —

Photo 01
Grüne Wand, Prototype 110 sq. m, Boardroom Hypo Vereinsbank, Munich, Germany 2005
Photo © Christian Richters, Münster, Germany. Courtesy of indoorlandscaping, Trier, Germany

The same living wall with additional plants, in the very same location, now a hotel, 12 years later
Photo © The Love Lace Hotel, Munich, Germany 2017-2019



Section © DETAIL 12/2008. www.detail-online.com

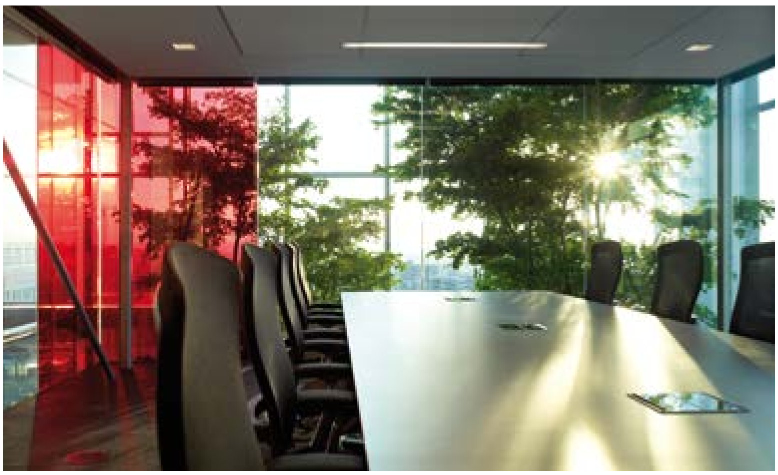
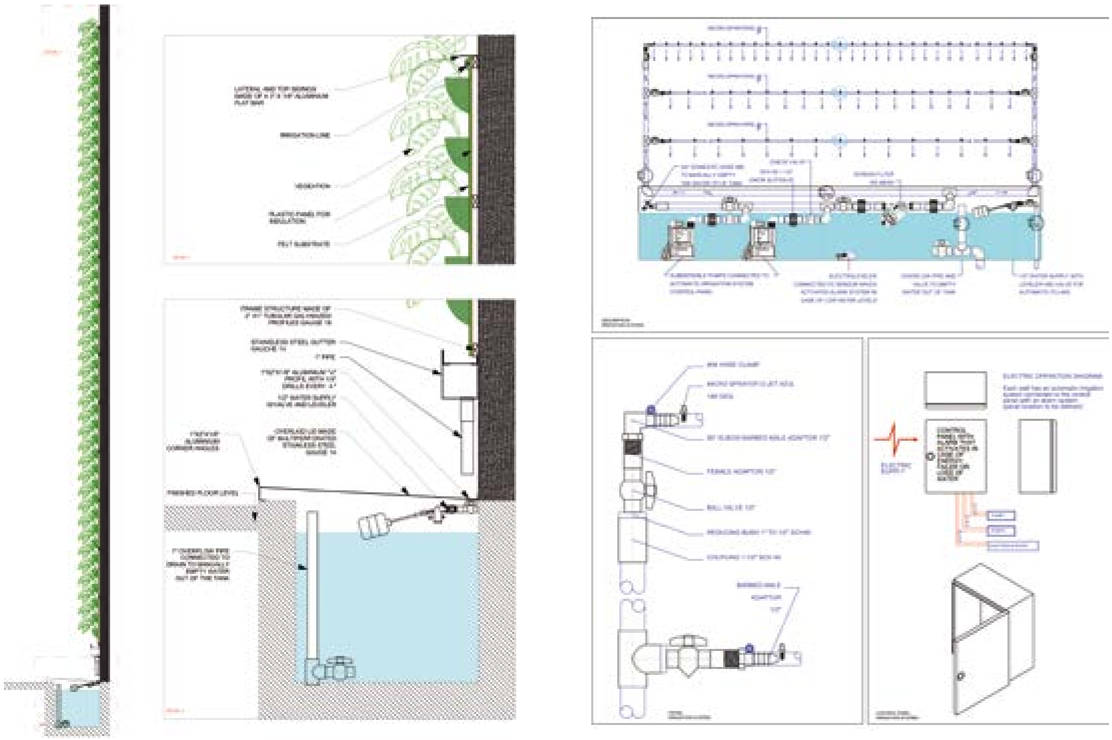


Photo © Gerry Zemp, Bern, Switzerland. www.aplantis.ch

Planted walls internally

Green, planted walls are used in internal situations for the positive effect they have on people psychologically and physiologically. As well as improving the indoor air quality to a measurable degree, they can help to reduce stress. lf a great use of resources is necessary for their production, however, or if long periods of artificial lighting are necessary for the upkeep of the plants, the arguments in favor of green walls as an energy-saving measure no longer apply. The demands of building clients and the potential of ecological engineering increasingly point in the direction of using vertical planted surfaces for air conditioning and indoor climate control.



Bearing the name Green Wall, this development is based on a principle of passive vaporization that results in adiabatic cooling. Using inorganic foam as the sub¬strate, the air emitted is free of germs. The purpose of the foam is not to retain water, but to ensure a good drainage capacity in order to give off as much moisture as possible. This system functions only internally. The plants are initially cultivated in a greenhouse on 400 x 600 x 50 mm two-layer foam slabs. The units are then fixed in position vertically with offset joints, which grow together in time. The plants are kept trimmed with shears to maintain a length of 5-7 cm. The plant types used to achieve an even surface are Ficus pumila and Philodendron scandens. Other species are being tested. In addition, varieties of fern, orchid and anthurium are used. The vegetation should be tended and the water runs cleaned every three months. A Green Wall installation can be found in the Hypo Vereinsbank in Munich.

Controlled, germ-free air-moisturisation with pre-cultivated foam-based panels by indoorlandscaping, agency for new green strategies, Trier and Munich, Germany.

Brand name: Grüne Wand;
www.indoorlandscaping.com

Diagram of Green Wall air-moisturisation system by indoorlandscaping —

a Ø 170 mm tubular steel supporting structure

b irrigation with nutrient solution

c 20 mm polystyrene bearing panel with clip fixings

30 mm foam substrate 400/600 mm (16“ x 24“)
Vegetation layer: Ficus pumila, Philodendron scandens, etc.

d mdrainage gutter for excess water

The physical principle is a passive vaporization with an adiabatic cooling capacity of 50 - 110 W per sq. m and an evaporation rate of 1.8 - 3.8 liter per sq. m per day.

The first Green Wall prototype has been already installed in 2005 in the boardroom of the former Bayerische Staatsbank which later used to be the Headquarters of Hypo Vereinsbank. Until January 2019 the green wall was still fully functional and well maintained in "The Lovelace Hotel" a so-called hotel happening, a pop-up hotel concept as an interim solution for the up-coming modification of the building by its new owner the Rosewood Munich, to open in early 2023.

The Grüne Wand system has been awarded with the ‚Focus Green 2008' in Gold Design Award by the renowned Design Center Stuttgart and was therefore the first ever design awarded vertical greenery system, which proofs its idea as an integrated architectural design component.

In the following years the by then outsourced distribution of the system was a kind of tricky. Beyond the former high price for the installation, long-term maintenance and visual control by an experienced gardener on a defined interval was always the key for the success of any living wall system. Note: The former price was approx. € 4,000 EUR per SQ.M depending on the size. A full package with a lump-sum pricing including pre-cultivated phenolic resin foam panels, superstructure, irrigation, stainless steel water channels, and water treatment system. Including an electronic control system, plant-physiological lighting for an even growth and its vitality, transport, and installation. Followed by a 3-month set-up maintenance, and 5 years warranty regarding the terms of construction law (namely VOB) in Germany.

Commitment of the client at the very beginning of the project stage could easily change during the process that e.g. based on contract issues within the facility management and/or

Steve Hall © Hedrich Blessing Photographers, Design by Perkins+Will. Courtesy of indoorlandscaping, Trier, Germany

changes of the responsibility the maintenance contract could be either reduced to a minimum and/or could be even cancelled. In our experience approx. 10% of the installation costs are equal to the financial efforts of the annual maintenance; meaning over 10 years you spend the same amount for maintenance as you spend on the installation at the very beginning.

Our design approach using just one main species (sometimes accompanied by 2-3 different plant species) as a monochrome wall texture with a thin constructive depth was always a visual highlight in the interior architectural context, but also a kind of fragile and not really sustainable approach since we almost every time did need additional plant-physiological lighting for both the even growth and to guarantee its vitality (vs. LEED points).

The passive evaporation provided by the foam panel with its huge surface was always a huge advantage to all other available systems on the market. With its calculable and controllable adiabatic cooling performance it is a great plus for projects focusing on climate engineered solutions. Back then we called it functional green.

What brings me from the past to the now and to questions popping up in my head —

How can we provide a new generation of living walls for the interior market? Could we change our fully covered approach to an only partly vegetated wall inspired by the role model of vegetated rocks in nature? Back to low-tech solutions which require less visual check and less manual care of its creator and its user and therefore less expensive external maintenance service.

So that the taking care, the watering, the pruning can be done by the people living in, and the employees working in the indoorlandscaping spaces. And that this will be a welcomed break of the daily business and the real value of a living wall: the re-connection to nature and something living we / they have to take care of — in our more and more digital world.

"Fools hurry, clever ones wait, wise ones walk in the garden."

— Rabindranath Tagore

How can we act with the new generation of living wall regarding certifications like LEED, BREAM, WELL-BUILDING and others instead of using valuable tab water for

irrigation and expensive electricity for the artificial illumination of plant walls. How to improve the sustainability and the life cycle assessment by using cradle-to-cradle principles?

Around mid of 2007 i have been in invited by former the trespuntos (...) team members to D. F.,

the capital of México where I did come in contact with Yaël Ehrenberg, an Agronomic Engineer with master's degree in Landscape Ecology, and an associate degree in Landscape Architecture and her multi-disciplinary colleagues Ania, Tomás, Fernando, Francis and Dorian. Yaël and me met first in the City of Miami on one of my trips through the nurseries of Florida within my very first project in the United States for the renowned Chicago-based architects Perkins + Will and the Bank of America Headquarters in Charlotte, North-Carolina.

trespuntos already led late 2007 into the foundation of verde360°, a company based in México City mainly focused on the design, installation and maintenance of exterior living walls. Yaël is now based in San Francisco. verde360° is still operating with its co-founders, father and son, Jacques and Francis Vermonden and their team.

2. THE MEXICAN EXPERIENCE

Yaël's background with verde360°

My first introduction to a living wall was on a visit to Paris in 2006. Standing in front of Patrick Blanc's project at the Musée du Quai Branly, I was truly fascinated by the idea of covering a whole building facade with a carpet of vegetation. I had seen it before with the landscape architecture of Roberto Burle Marx (by the way: Marx's father Wilhelm Marx was coincidentally born in Andreas' hometown Trier in Germany) in Brazil, and in vernacular buildings of some regions of México where succulents, ferns, moss and wild plants grow and thrive in between the cracks of stone, brick walls and tile roofs, but never in a structured technical way that Blanc had employed. My first thought was how magnificent it was as a work of art, an enormous live painting made of ornamental plants, and I became inspired to do something like this in México.

Nike Sportswear 1902, Condesa, México City 2008 in collaboration with architect Sury Attié. Yaël Ehrenberg, Till Straumann

The opportunity came a year later in 2006 when I got together with a group of young "out of the box" entrepreneurs in the field of architecture and design. We tried to find companies or people who had experience in this field but there was almost no information out there on the internet, and the few we found out about (ELT Elevated Landscape Technologies established in 2001 and GSky Plant Systems established in 2004) were out of reach because it would be too complex and expensive to outsource a project from abroad.

We decided to do it ourselves with materials produced in México. Through our research process we were introduced to Andreas Schmidt's work with indoorlandscaping. We got in touch with Andreas to better understand his minimalistic technic, and went to Germany to meet him and see several of the Grüne Wand projects. We realized that his elegant technic was best fit for indoors, and although it could work in México, it would be quiet expensive due to the required infrastructure that would need to be imported. While we did not directly utilize his technique, our contact with Andreas developed into a close collaboration throughout these years, exchanging experiences, technical advises and design ideas.

When I co-founded verde360° in México in 2007 with the idea of realizing a vision of building living walls in our home country, many landscape architecture companies, concerned with the contamination and overpopulation in urban cities were already developing projects with sustainable architecture. Therefore the idea of using the vertical space of buildings for gardens was attractive in all senses and easily embraced. It was beautiful to the eye and soothing to the senses with vegetation added to otherwise unused vertical surfaces. Living in a country with a wide range of climates within the temperate and tropical zones and having México City just neighboring the major area of ornamental plant production in the country (states of Puebla, Michoacán, Morelos, and Estado de México) enabled a more exciting and useful start with a wide variety of flora for outdoor living walls.

Following the footsteps of Patrick Blanc, we adapted his technique, a hydroponic system consisting of a metal frame attached to the building, with waterproof backing, felt as a growing medium, and an automatic irrigation system. We experimented during 2 years with different kinds of felts, structures and irrigation methods, trying plants in different stages of growth from plugs to using 2", 4" and 6" potted plants until we finally found a solution that worked for us as it could be built within a sustainable Mexican context and reality.

Three major technical factors for the living wall system proved challenging: The felt; finding the correct density that could best absorb and retain moisture and where the roots could grow and spread in between the fibers. The waterproof backing or plastic panel; we needed a material that could be easily stapled and fixed to the supporting structure without cracking and did not want to use PVC because of its harmful environmental impact. The control panel for the irrigation system; we needed a system that could be programmed for short interval irrigation periods.

We landed on using two layers of a 100% synthetic felt made of recycled polyester, fixed on a plastic panel made of recycled polyethylene from plastic toothpaste tubes that in turn would be reclaimed and recycled to create new living walls.

As a result of our use of these materials, produced in México, a new business industry has been made available to the growing market of living wall companies. Our automatic irrigation system, tailored for the characteristics of each individual project, is based on micro-sprayers that effectively soak and spread the moisture on the felt layers. A tank that stores the water that drips down, which is then pumped, and used again to irrigate the wall to ensure the use of water is maximized.

When we first started designing and building living walls, the main reason for people wanting to have one was purely aesthetic, creating a landscape on a vertical surface has a very strong visual impact. A second reason was this new possibility of using vertical surfaces as spaces for gardens, and after México hosted in 2010 the first major Green Roof Congress in Latin America, a better understanding of the benefits of different types of green infrastructure became another reason, and furthered promotion and implementation of living walls in our country.

I have seen that in this short period of time, the demand for living walls in México has rapidly grown and where it was once almost impossible to find the resources to make them, we now see them everywhere in different forms and sizes. However my feeling is that this rapid growth has not been accompanied by a full understanding, and wise engagement of how to maintain the living walls in a sustainable way. We have

Tori Tori Restaurant, Polanco, México City 2010 in collaboration with architect Michel Rojkind.
Yaël Ehrenberg, Paúl Rivera, NYC, Courtesy of Rojkind Arquitectos, México D.F

Sexy Jeans, México City 2012 in collaboration with architect María del Mar Lozano Ahumada

Suites Pensylvania, Colonia Nápoles, México City 2014

yet to close the gap of re-connecting with nature as Andreas mentions, not simply as a business and fashion statement created with a rhetoric of sustainability, but more importantly to extend the vitality of the living walls by properly addressing our opportunity to benefit our world through a sustainable implementation.

In México there has been a boom industry of synthetic vertical gardens and if you drive around the city where there once was a living wall, you will now see that they have been replaced by synthetic materials.

Could it be that we not only live in a more digital world but also in a world where our daily activities are done at a very fast pace? It seems to be that our generation of humanity expects immediate results, products and services are made and delivered in less time and this also applies to the living walls. But the longevity of the living wall not only depends on the maintenance, other factors that play an extremely important role are the steady supply of water and electricity to activate the lighting (for the indoor ones) and irrigation system. Our experience in main urban cities in México is that these services are not 100% reliable. We frequently have power outage and specific to México City, water shortages. This is when we have seen how vulnerable the living wall system can be.

With verde360° we work to ensure the health of our living walls through the inclusion of a maintenance agreement. Depending on the type of project, we require within the design and budget a permanent infrastructure to access and facilitate the maintenance. If this infrastructure to support maintenance is not accepted then we will not do the living wall. In addition, due to the long distances that have to be covered to get from one living wall to another within México City and neighboring states, and due to the heavy presence of traffic, frequently the contract has to include training the client's staff as well, until we find the right moment to transition maintenance of the living wall to their own staff. This not only ensures the live span of the living wall but it also helps to educate the customer and the caretakers.

Also difficult is conveying to our customers an understanding of the nature of plants, their growing seasons and capacity to fully regenerate again after a period of rest, trimming or pest recovery. In a commercially oriented setting, this has not been easy. An acceptance of seeing temporary patches of brown leaves, and the patience of waiting for regrowth and blooming periods is not something that is yet considered acceptable, especially in projects that are done in hotels, restaurants or public spaces. In private residential projects, the tendering and maintenance of green areas is generally done by in-house staff or hired gardeners, very rarely is it done by the owner him or herself. Again, this makes it difficult to convey a critical understanding of the cycles of nature.

Yaël Ehrenberg and Andreas Schmidt. San Francisco and Trier, January 2019

In my experience, the most successful designs of living walls have been the ones where there has been enough time to dialogue and meet with the architects and end-customer during the planing and construction phase, and when I have had sufficient time in finding and selecting the right plants for the right place, and/or when I have used plants that are very small, mostly in a 2" pot and plug form, in these sizes plants adapted more easily to this artificial hydroponic environment, and it takes around 8 to 12 months or more for a living wall to become fully covered in vegetation. In contrast, in projects where there is the pressure of a delivery date, the design outcome has a different feel, plants and plant sizes are selected based on the availability rather then the right plants for the very particular environment you are working within. This prioritization of quickly achieving an end result, leaving less time to scout, find and grow the ideal plants may deliver a more monochromatic living wall, with less diversity of species. Plants may also be bigger in size to obtain a faster green filling effect on the living wall, while disregarding the longer-term consequences.

While these obstacles may appear daunting in the moment, they have also opened an opportunity in the landscape community. As a result a wide variety of different living wall systems have and are being created, and the use of integrating solar panels and gray-water has yet to be explored in more detail. We have already succeeded in converting vacant gray areas into wonderful, enjoyable spaces, now I am most excited about the potential of our green industry to truly unlock a sustainable approach to living walls. This can be achieved through a more thoughtful partnership between urban planners, architects, landscape architects and the customers who wish to achieve a truly living work of art that benefits the building and takes advantage of the environment. Maybe return to the use of vernacular buildings where vegetation is an integrated part of the construction materials? Maybe we need to talk and think more about taking care of our own plants, slowing down, observing and appreciating the cycles of nature?

The idea of unique custom-made living walls has been fundamental in my drive to design and build them, by unique I mean living walls that evolve slowly in time, that are tendered by the owner and that create a true sense of fondness and understanding of how plants grow and behave.

While reviewing these lines between the turn of the years 2018/19 I am going new ways and I am currently starting a new generation of plant walls inspired by partial planted walls you'll find on rocks in nature. Based on the fantastic sustainable, 100% natural, Portuguese Gencork material, indoorlandscaping is more than happy to introduce a fully new approach. From a living wall pioneer with a 21+ years experience to a purpose-driven green mission into a green future.

REFERENCES

AIT 04/2007. Grün. Technical solutions. Planted interior walls. Pages 156-158.

ARCHITECTURE TODAY 11/2007. EcoTech., pages 16-19.

DETAIL 12/2008. Living Walls. Vertical Gardens – from the Flower Pot to the Planted System Facade. By Frank Kaltenbach. Pages 1454-1466.

HORTITECTURE. The power of architecture and plants. Published 2018 by Jovis.

IDAS Institute for Design and Architectural Strategies, Prof. Almut Grüntuch-Ernst, Braunschweig, Germany. www.idas.tu-bs.de

CHAPTER 10

NATURE-BASED SOLUTIONS AND THE IMPROVEMENT OF AIR QUALITY IN CITIES

Jorge Adán Sánchez Reséndiz
Member of the Experimental Spaces Commission in the Innovation and Technology for Development Center of Universidad Politécnica de Madrid

SUMARY

In 2050 urban populating are going to be increased by 2.5 billion people, and with it, the problems of water supply, food, housing, services, and gas emissions to the atmosphere, worsening the air quality problem and contributing to the global warming.

The need to face global warming and its side-effects remains one of the major challenges to human civilization and could not be more critical. According to WHO, nowadays around half of the world's population (48%) lives in cities, where more than 45% have a poor air quality (air composition has a high amount of COx, NOx, SOx, O3, VOCs, PM2.5 and PM10), affecting more than 1.6 billion people. Causing every year, more than 7 million deaths related to air pollution (both indoors and outdoors).

The overpopulation of cities joined with the lack of green spaces, worsen this situation, highlighting the urgency to improve this condition through the integration of nature in our buildings and urban furniture. Since in addition to purifying the environment (capturing and purifying air pollution), it also contributes to lower the temperature of cities (decreasing urban heat island effect), to raise relative humidity and increase biodiversity in cities.

This work highlights an example of Nature-Based Solutions used to combat urban air pollution. Offering data on their effectiveness and contributing to their dissemination and replicability throughout the world.

KEYWORDS

Nature-based solutions, urban air quality, air-pollution, NBS furniture, MUAC.

INTRODUCTION

Technological innovation has been a constant of postmodern man, the records guarantee that the most important development in the history of humanity has been generated in the last 200 years and even then, there are great problems and inequalities that must be faced and solved.

One of these problems is that humans must coexist with polluted environments, principally in those places of greater development that we call cities. Urban environments since the appearance of the automobile, have been giving more and more ground to the roads, turning their soil into an impermeable surface, causing problems of overheating and loss of biodiversity. And as a residual problem, the worsening of the air quality. The air pollution is composed of gases (NOx, COx, SOx and O3 among others) and particles in suspension (PM10, PM2.5 and ultrafine particles), which vary in size and chemical composition while being transported through the atmosphere.

Efforts have been made to address this problem since the 1990s, establishing laws and regulations to restrict the number of gases emitted by vehicles, but even so, the air quality of most cities is far from ideal for human health. Some of findings reveal the incidence and prevalence of childhood asthma and wheeze [1], asthma exacerbation [2], impaired lung function [3], and cardiovascular mortality and morbidity [4], among other diseases related with a poor air quality. Other studies shown this direct relationship between environmental pollution with chronic conditions in humans:

- Long-term PM10 exposure, even at a concentration lower than current European air quality standard was significantly associated with incident Cardio Vascular Diseases (research findings with Nord-Trondelag, Norway as control region) [5].

- We add to this evidence base demonstrating that between 18% to 38% of all childhood asthma cases (research findings with Bradford, UK as control city) may be associated with air pollution [6] and depends on the pollutant and exposure time.

- There has been a rise in lung cancer patients specially in non-smokers and is proven to be linked with the increase of air pollution levels in cities (research findings with Xuanwei, China as control city) [7].

- Larger non-permeable surfaces increase in population, services, vehicles, have increase around 40% of CO_2 emissions in large cities (research findings with Mexico City as control city) [8].

- Gaseous ambient air pollution is associated with a range of cardiorespiratory outcomes in middle income countries [9].

- Real Driving Emissions overpass post Euto 6 LDVs Directive due an unrealistic driving cycle and a lenient framework that allows interpretation, especially on most Low Emission Zones [10].

The type of pollution varies in each country, depending on the type of fuel used, for example, in Europe one of the main problems is the high amount of NOx in the air (diesel is used as the main fuel), while in the US the values of particles in suspension are much higher (gasoline is used as the main fuel). And what to say about the ultra-high levels of PM10 / 2.5 suspended particles in countries like China and India where a constant gray mist accompanies its inhabitants for most of the year.

Unfortunately, this situation is spreading more and more, due to the movement of air generated by the rotation of the earth, causing this problem to move around the globe and affecting places where *per se* there is no such problem.

The integration of nature in the city, has gone from being an aspiration to improve the aesthetic aspect of buildings, to become a necessity to improve the general living conditions of its inhabitants, as a better hygrothermal comfort (lower temperatures , a greater surface for the absorption of rainwater and an increase of humidity and biodiversity) and improvement of the quality of the air (absorption of gases and particles in suspension).

The objective of this work is to make a representative compendium of Nature-Based Solutions NBS, focused on improving the quality of urban air, both indoor and outdoor.

AIR POLLUTION & NATURE-BASED SOLUTIONS

The world lives in a series of large-scale changes, originated without any doubt by the human being, resulted from the increase of global population and the lifestyle in which the capital rules the rest of things. Since the second half of the twentieth century, there have been large migrations from rural to urban space, causing the uncontrolled growth of cities. Nowadays, almost half of the world's inhabitants live in cities and in turn, half of these cities have a poor air quality [11], affecting to more than 1.6 billion people and causing the death of more than 7 million each year.

The location of the vegetation within the cities, in most cases, is distributed unequally. Some studies delve into these differences, stipulating that the richest neighbourhoods are the ones with the largest parks and wooded areas, while the poorest neighbourhoods have a greater number of paved areas that accentuating the poor air quality conditions. in turn, this phenomenon is increased among the countries level of development, as in the most developed countries have cities with a greater number of green areas, while most cities in the poorest countries, hardly reach the minimum 9 square meters of vegetation per inhabitant stipulated by the World Health Organization as indispensable for a good general and mental health[1].

Thus, the integration of urban furniture with vegetation is an important element to improve the conditions to which citizens are exposed. In this sense, there are different technological developments to contribute to cleaning and purify urban air, which uses both mechanical and biological means, latter's advantage is the use of nature-based solutions, which foresees innovations with low energy consumption and a low carbon footprint.

Since NASA[2] made public a study stating that vegetation can absorb and purify the interior spaces of buildings, countless studies have been carried out to verify its effectiveness. The plants contribute to a greater or lesser extent depending on their morphological conditions, to a greater surface for the catchment, better results, but also, the leaves must have certain characteristics of roughness and adaptability to the different environments.

The constant evolution of the nature-based solutions systems has given rise to different technologies going from biofilters that improves air conditioning in buildings to mixed systems (mechanical-natural) that increase the effectiveness of uptake and purification, forcing nature to work in all its extension, from the roots and their microorganisms, up to the leaves, which absorb particles in suspension and does a gaseous exchange as a result of photosynthesis (absorption of CO_2 and generation of O_2 and water vapor). Here again, the morphology of the roots of the plants has an important role, as those with thicker and diversified roots, can retain a greater number of particles.

These NBS to improve air quality in 2 types can be divided by those that don't use any type of mechanical system to enhance the cleaning power of plants, and those with a mixed system that integrates mechanical means. These NBS developments, in turn, can be subdivided into solutions for indoor and outdoor.

An example of NBS for outdoors is the City Tree already installed in several European cities and developed by Green City Solutions. This NBS uses a mix of plants and moss to capture particles in suspension and absorb diffe-

---

[1] *York, N. (2015). HABITAT III ISSUE PAPERS 11-PUBLIC SPACE. Retrieved from http://habitat3.org/wp-content/uploads/Habitat-III-Issue-Paper-11_Public-Space-2.0.compressed.pdf*
[2] *ntrs.nasa.gov/search.jsp?R=19930073077*

Fig 1. Example of a city tree in London UK

rent types of gases such as NOx, although this kind of vegetation can represent a problem for its replicability in different environments and climatic conditions (as this species needs for controlled environments to survive), the company declares that they can maintain the ideal conditions for their growth and maintenance thanks to an irrigation and air conditioning systems placed behind the vegetation.

Even if this represents an increase in the energy consumption and a higher current expenditure, this device has shown its efficiency to purify the air through the last years and proven that exist a market eager for this type of technological developments. However, the product has several drawbacks such as its large size, its weight, the vegetation because it uses the moss as a purification system, which consumes a high amount of to maintain the ideal conditions of humidity and temperature and finally the cost since each square meter costs around 3K€, hindering its scalability in countries with lower incomes and more adverse climatic conditions.

On the other hand, an example of indoor NBS would be Botanical biofilters in form of Plant Pots designed to purify interior spaces with a system that uses both leaves and microorganisms from the roots. It would be the updated concept of a hanging pot that has exposed roots in the air. Its principle is to leave exposed to the air, part of the substrate with roots, so that either by mechanical means or simply by this free exposure, gases, and volatile organic compounds can be absorbed.Its effectiveness has been proven since phytoremediation studies have clearly demonstrated enhanced contaminate removal by rhizode- gradation and phytostimulation[3]. Also, other studies have shown the ability of theses botanical filters to remove VOCs and CO_2 and modulate temperature and humidity of indoor environments.

---

[3] *E. Pilon-Smits, Phytoremediation, Annu. Rev. Plant. Biol. 56 (2005) 15–39.*

Fig 2. Hanging pot with flowers

To contribute on solving this problem, researchers at the Innovation and Technology for Development Centre of the Polytechnic University of Madrid have developed a Nature-Based Solution in the form of a vegetation tower for the collection and purification of polluted urban air, by the name of Modules for Urban Air Cleaning or MUAC.

MODULES FOR URBAN AIR CLEANING (MUAC)

The MUAC project has been funded by the European Institute for Innovation and Technology (EIT) within a Climate-KIC Call, and its main goal is to contribute to creating Green and Resilient Cities. It has been designed to become an important element of the urban landscape of cities, increasing vegetation in large paved surface, reducing GHG emissions (due to its double purification system) and contributing to improve the urban microclimate (hygrothermal and acoustic).

Their indirect impacts are:

1. To provide the citizenship with an important role to reduce the air pollution (Trough democratizing climate risk information in real time) with compelling evidence of the pollution levels, and by means of luminous signs, show citizens the conditions of their air quality.

2. Accelerate clean urban mobility, with the real-time pollution information, citizens would decide how to act to mitigate risks (use protection) and decrease emissions (like deciding whether to use public or alternative means of transport). This NBS seeks to generate a dynamic combination between infrastructure and society to transform cities into more permeable and resilient places.

3. Improve microclimatic conditions due the benefits generated using vegetated urban modules in large paved surfaces.4. Increase

the feeling of well-being in society due to the increase of vegetation in poor neighborhoods commonly scarce of green areas.

5. Increase pedestrian mobility by increasing urban greenways and improving microclimatic conditions.

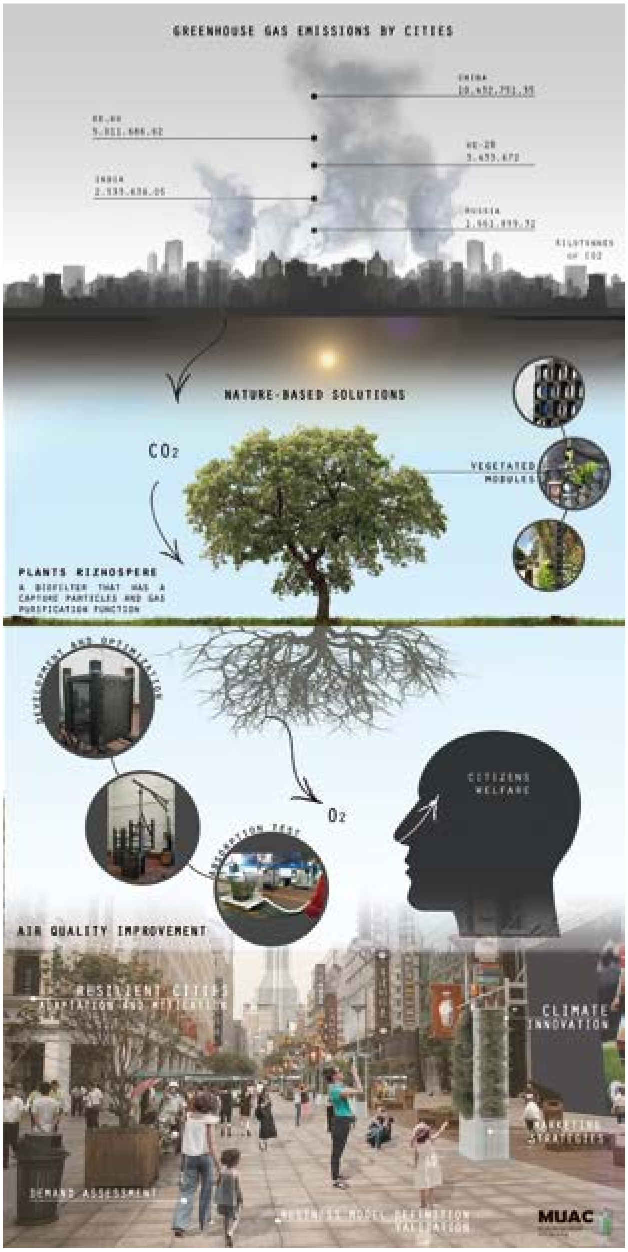


Fig 3. A brochure describing the MUAC's components

Its main features are:

- Low Carbon Emissions: The MUAC modules are made with lightweight steel profiles and plastic modules, 100% recyclable, decreasing its carbon footprint and allowing it to opt for an ecological mark.

- Adaptability: Use of native vegetation for an easily adaptation to different environments and climates.

- Purification System: The vegetation works as a biological filter to capture particles (PM) and purify polluted air (COx, NOx, O3 etc.).

- Affordability: It multiplies the surface area for capturing particles and gas purification (4 sqm of external vegetation and 4 sqm of internal rhizosphere that functions as biofilter) making the MUAC a product with great value for money, with the possibility of being self-financed through the insertion of advertising spaces.

- Efficiency: The filtration system can pass up to 70 m^3/per hour of air through its interior.

- Dimensions: It occupies a small area of only 0.49 sqm, which allows installing it in narrow spaces such as sidewalks, two-way streets with small ridges, as well as dividing elements for public spaces (squares, walkways, sports facilities, schools, etc.).

- Occupancy rate: Up to 4 sqm of vegetation can be placed on 0.49 sqm multiplying by 8x times the occupied surface area.

- Modularity: It's formed by modular pieces, which are easily repairable and/or replaceable, an aspect that allows reducing the cost of installation and maintenance.

- Scalability: Its modularity, dimensions, environmental advantages (uptake and filtration of air pollutants, increase of vegetation in highly paved areas, improvement of microclimate conditions around the modules, increase in vegetation for wildlife) social advantages (It has been shown that there is a correlation between the improvement of human behavior, related to the increase of vegetation in cities), and the economic advantages (an affordable price and the possibility of being self-financed through the integration of advertising), make the innovation easily scalable.

VALIDATION OF THE INNOVATION

Reference analysis

The high amount of NOx is one of the main responsible for the health problems in Spain. The integration of vegetation as a biological element for the improvement of air quality, surpassing in some cases those mechanical filters. Croome et al, make a comparison of a specific system of biofiltration with a traditional system of air purification by electrostatic methods and a more advanced system by means of cold plasma (or non-thermal plasma), showing the great advantages of nature, to improve the air quality, above the rest of technologies.

"Electrostatic air filter is theoretically considered as permanent and the filtration efficiency of the particles can achieve 82% to 94%. Cold plasma (or non-thermal plasma) air filtration is effective in the case of fungal spores and airborne bacteria and can achieve 85%–98% decontamination even with low exposure time (0.06 s). The Trombe wall system constructed of breathing wall panels can achieve high filtration efficiency (99.4%) in the case of PM10 and at extremely low blocking rate (with 60 years of service life), even in polluted urban environments. Biofiltration technique is recognized as 'most easily adapted to mechanically ventilated building or on the pit fans of naturally ventilated buildings".

Validation trough experimentation

Different studies were carried out to measure the efficiency of the system to absorb two types of gases, COx and NOx. The first of the

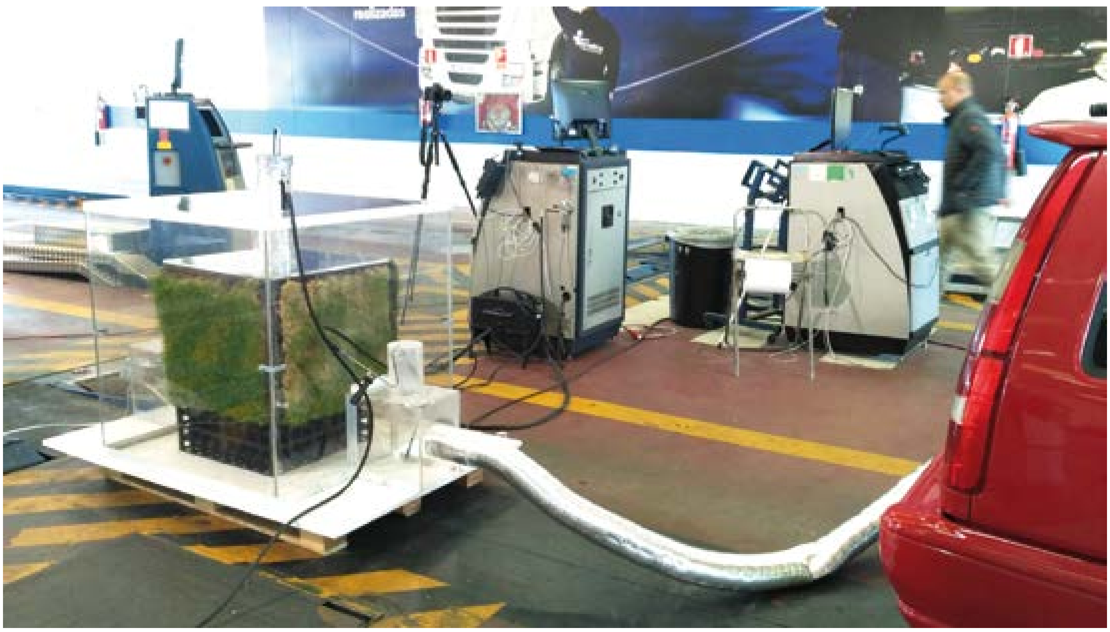


Fig 4. Experimental test carried out in the ITV las Rozas, Madrid

Fig 5. Experimental test carried out in the itdUPM headquarters

studies were carried out in the facilities of the Vehicle Technical Inspection Center (ITV for their acronym in Spanish) of Las Rozas in Madrid, where we were able to measure the percentages of direct absorption of the vegetation (1 square meter of grass) before different types of emissions produced by three different vehicles (a 12-year-old diesel bus, a 9-year-old diesel vehicle and a 12-year-old gasoline vehicle.

Other tests were also carried out at the itdUPM facilities (Center for Innovation in technology for human development) where the capacity of the system to absorb and purify NOx. Tests were conducted by measuring the emissions of two diesel vehicles prior to 2007 (manufactured under Euro 4 standards) with all loads placed (engine idling, air conditioning on, lights and lights on, windscreen wipers on, stereo in high volume, flashing lights on, anti-fog system activated and driving assistance turned on).

RESULTS

Efficiency rates

The ITV tests were done by using a test box with three compartments that allowed us to measure the composition of the gas when entering the box, after having been filtered by the vegetation and finally the composition of the gas that passed through the box without being filtered by the vegetation. The results showed that the filtered air from the vegetation reduced the composition of the COx gas by up to 35%, while the composition of the gas that passed without being filtered directly at the outlet of the box had a composition 5% lower than the entering measure. Is important to highlight that the exchange of COx by oxygen is generated only through a process of photosynthesis (when the vegetation receives direct sunlight) the rest of the time works as a filter that absorbs the gas, storing it within the substrate of the vegetable module.

The results of the tests done in the itdUPM showed that 1 square meter of vegetation (1/4 of the vegetation of a MUAC) has the capacity to absorb up to 48 ppm equivalent to 98 mg/m^3 of NOx in a time of 120 minutes, with which a MUAC tower could clean up to 396 mg/m^3 of NOx every two hours or 4752 mg/m^3 every day. And unlike the COx test, the interaction of the sun is not necessary for the system to absorb the NOx gas since this function is done by the microorganisms that inhabit within the roots and the substrate.

Level of Acceptance

Besides to validating the efficiency of its purification system, researchers wanted to know the public level of acceptance of technological innovation through the realization of a case study. This case was conducted in the event Imperdible 03, organized by the COTEC foundation for innovation, demonstrating that this innovation is a friendly and interesting product for the end user; the citizens of Madrid who live and breathe the polluted air of the city... The most representative data is that 97% of a total of 182 interviewees sees MUAC as an important product suitable to be placed in the streets of their cities and up to 87% mentioned they would buy a MUAC to place it in a nearby environment to your workplace. Regarding the aesthetics of the system, about 83% defined the MUAC a "nice" or "beautiful" object. The words innovative, green, ecological, clean and useful were the most used to define the MUAC in a word. Finally, the 77% of surveyed people, are in productive age (between 20 and 60 years old) and would be the target people to be convinced for the integration of these technologies in cities is possible.

Air quality design. Adan Sánchez

CONCLUSIONS

Technological innovations developed from Nature-Based Solutions represents a great opportunity to improve the environments of our cities. Technologies such as MUAC that integrates vegetation into an efficient system for air purification can be the solution to reduce the inequality of green spaces in cities. This friendly technology, to purify and make more comfortable the environment that surrounds it, can work 24/7 the 365 days of the year and with low environmental impact.

Results from the study carried out to know the interest and acceptance of people, shows that this type of technologies no longer represents an aspirational innovation but a necessary and urgent product to be used in real environments.

Both the bibliography and the experimental tests to validate the efficiency of the MUAC put into perspective the power of nature to absorb and purify the gases and suspended particles that affect our health.

Although a single product does not have a great impact on the environment, the replicability and scalability of nature-based solutions such as those mentioned in this chapter could represent an effective way to improve poor air quality in many cities in the world. Learning to be resilient and using all the means so that our cities are so, will perhaps be the only means to coexist in a future full of changes.

"It's your reaction to adversity, not adversity itself that determines how your life's story will develop."
Dieter F. Uchtdorf

REFERENCES

1. *J Gasana, D Dillikar, A Mendy, E Forno, E Ramos Vieira. Motor vehicle air pollution and asthma in children: a meta-analysis Environ Res, 117 (2012), pp. 36-45*

2. *W Yang, ST Omaye. Air pollutants, oxidative stress and human health Mutat Res, 674 (2009), pp. 45-54*

3. *J Samet, D Krewski. Health effects associated with exposure to ambient air pollution J Toxicol Environ Health A, 70 (2007), pp. 227-242*

4. *ASV Shah, JP Langrish, H Nair, et al. Global association of air pollution and heart failure: a systematic review and meta-analysis. Lancet, 382 (2013), pp. 1039-1048*

5. *Cai, Y., Hodgson, S., Blangiardo, M., Gulliver, J., Morley, D., Fecht, D., … Hansell, A. L. (2018). Road traffic noise, air pollution and incident cardiovascular disease: A joint analysis of the HUNT, EPIC-Oxford and UK Biobank cohorts. Environment International, 114(March), 191–201. http://doi.org/10.1016/j.envint.2018.02.048.*

6. *García-Yee, J. S., Torres-Jardón, R., Barrera-Huertas, H., Castro, T., Peralta, O., García, M., … Ruiz-Suárez, L. G. (2018). Characterization of NOx-Oxrelationships during daytime interchange of air masses over a mountain pass in the Mexico City megalopolis. Atmospheric Environment, 177(x), 100–110. http://doi.org/10.1016/j.atmosenv.2017.11.017*

7. *Wang, G. Z., Cheng, X., Zhou, B., Wen, Z. S., Huang, Y. C., Chen, H. Bin, … Zhou, G. B. (2015). The chemokine CXCL13 in lung cancers associated with environmental polycyclic aromatic hydrocarbons pollution. eLife, 4(NOVEMBER2015), 1–23. http://doi.org/10.7554/eLife.09419*

8. *Velasco, E., Perrusquia, R., Jiménez, E., Hernández, F., Camacho, P., Rodríguez, S., … Molina, L. T. (2014). Sources and sinks of*

carbon dioxide in a neighborhood of Mexico City. Atmospheric Environment, 97, 226–238. http://doi.org/10.1016/j.atmosenv.2014.08.018

9. *Newell, K., Kartsonaki, C., Lam, K. B. H., & Kurmi, O. P. (2017). Cardiorespiratory health effects of particulate ambient air pollution exposure in low-income and middle-income countries: a systematic review and meta-analysis. The Lancet Planetary Health, 1(9), e368–e380. http://doi.org/10.1016/S2542-5196(17)30166-3*

10. *Hooftman, N., Messagie, M., Van Mierlo, J., & Coosemans, T. (2018). A review of the European passenger car regulations – Real driving emissions vs local air quality. Renewable and Sustainable Energy Reviews, 86(July 2017), 1–21. http://doi.org/10.1016/j.rser.2018.01.012*

11. *WHO Global Ambient Air Quality Database (update 2018) https://www.who.int/airpollution/data/cities/en/*

CHAPTER 11

ECOPRODUCTIVE ARCHITECTURE FOR MULTIFUNCTIONAL AND RESTORATIVE CITIES: FROM PHYSICAL FORMS TO ENVIRONMENTAL CONTRIBUTIONS

R. Andrés Ibáñez G.
Founder and Director of the Technical and Scientific Committee,
Green Infrastructure Network, Colombia
Founder, Ecoincremental Lab

This chapter explores the notion of building and site ecoproductivity supported on the premise that creation of environmental contributions is not restricted to natural or semi-natural sources, as it has been widely accepted, but that these contributions may be delivered by the built environment and considered eco-restorative in urban settings.Previous explorations on positive development and regenerative design have recently begun to examine the implications of transferring the ecosystem services concept to the architecture field under social economic and environmental concerns. This chapter focuses on the later by studying a site retrofit in Berlin, and introduces an ecoproductivity assessment method to instrumentalize the concept of ecotectural contributions in town planning, under a multi-functional and multi-scale perspective.

1. THE TECHNOSPHERE'S OVERSHOOT

The man-made world has profusely transformed natural ecosystems. In a few centuries, the impact of our economic and productive systems over the earth´s preindustrial state has been so profound that several circles of the scientific community refer to a new geological era, supported on evidence that humans have caused irreversible changes in the planet's anatomy. Plastic rocks, artificial islands and altered climate are just few manifestations of this emerging era: The Anthropocene. The transformation of the eco-sphere into the techno-sphere can be quantified by the overall weigh of objects, buildings and artificial commodities produced by humankind, which is estimated at 30 trillion tons. As this number continues to increase, there is evidence that the capacity of the ecosystems on earth to maintain operational balance and deliver vital benefits for humankind is diminishing. These opposing trends -one augmenting and the other diminishing- convey an overshoot relationship between the growing resources demand and the decline in the biocapacity of the planet. We have created a feedback loop that is negative to both the ecosystems and us because it has made our socio-natural systems unstable and moves it away of equilibrium.

Key world environmental organizations believe that the ecological overshoot began five decades ago. Since the 1970's, the rate at which humankind consume services and goods is greater than the rate at which the planet can generate them. As a result, human civilization is running on a critical unbalance that can be expressed through the concept of Earth Overshot Day, defined as the date in a given year when society takes all the resources that the planet is able to produce until December 31. In 2018, the overshoot happened on the first day of August, which means that current society runs on an ecological debt of 5 moths, from August to the end of the year. Although the overshot day has been questioned as an accurate method to account for all the present environmental unbalance, it provides a clear idea of the challenge we face, particularly in the most geographically ubiquitous human activity: Urbanization.

2. FROM URBAN ABUNDANCE TO MAN-MADE "SCAR-CITIES"

Cities are a paradox of human development: they were meant to improve the living standards and provide a wide array of services to human population. Ironically, current urban settings are the environments that most greatly threat human and non-human forms of life. Urban centers concentrate the demand for environmental services like clean water, air regulation or energy supply. But instead of generating these services, urban fabrics undermine the territory´s ecoproductivity by replacing natural areas with inert urban fabric. Grey infrastructure provides services that support our economic and social systems, but it creates major environmental unbalances. Consequently, cities have very little or no capacity to generate environmental services.

"Not exclusively but must noticeably, in urban regions and cities where the majority of people live nature and ecosystems are intensively used and appear to be more and more degraded/ destroyed. They develop into a state where they are no longer able to provide any services (MEA, 2005)".

From an anthropocentric perspective of sustainability, the concept of ecosystem services is essential to human well-being at a global scale; but urbanization, the most global activity, transforms naturally productive areas into inert landscapes made of hard surfaces. A crust of asphalt, concrete, steel, and other materials, replace biotic elements such vegetation, fauna and soil. This depletes the capacity of the territory to infiltrate water, provide clean water and food, regulate temperature, and deliver other key benefits for humans and non-humans. The expanded urban fabric also causes a fragmentation of the natural habitats that support biodiversity, which makes natural ecosystems weak to disturbances and changes. Urbanization is the major producer of negative environmental outcomes that harm natural systems and cause multiple environmental disservices that affect humankind.

Urban landscape is defined as the "area of human agglomerations with more than 50% of the surface built, surrounded by other areas with 30-50% built, and an overall population density of more than 10 individuals per ha". (Breuste, Haase et al. 2013). The first visible sign of the urbanization process is the adaptation of the natural terrain for human activities and their related infrastructure. Soft soil, swamps and water bodies are altered and replaced by different types of structural and impervious soil layers. In this process, topsoil is manufactured, relocated and compacted,

Ufa Fabrik. Berlin. I. de Felipe

which causes a number of issues: decay of organic matter, erosion and air pollution due to construction activity, contamination of the natural soil with heavy metals, change in soil composition that encourages the growth of invasive plant species, and depletion of the terrain's capacity to drain and infiltrate water, which ultimately produces a "chronic dying effect". This progressive soil transformation is the less reversible man-made form of desertification.

In its turn, sealed ground impacts the water cycle. As the natural land cover is replaced by hard surfaces, the urban landscape is exposed to great amounts of run-off water that washes pollutants like nitrates, phosphates and heavy metals into rivers, affecting wildlife and the natural process of sedimentation. To stand floods, cities must rely on artificial drains, underground pipes and large pieces of engineering like dams and ponds that become obsolete as cities expand, creating the need of grey infrastructure replacements and updates at great costs. Clean water is usually extracted from sources distanced from the city and conducted through pipes that desiccate and warm up the landscape.

Changes in water volumes and flows create thermal pollution that contributes to the heat island effect. Dark surfaces, poor shading, dense materials and reduction of evaporation increase temperature in cities. The urban fabric absorbs solar radiation, stores it, and releases it back to the atmosphere in the form of heat, raising the temperature of the air up to 9 Celsius degrees in comparison to natural surrounding areas. Subtle changes in the air temperature lead to alteration of climate and microclimate factors like wind and rain. As a result, cities experience more intense winds, rains and draughts, all of which increase the risk of economic and human losses.

Cities are home to the greatest environment-related cause of human casualties. Every year, polluted air kills approximately 8 million people. Urban activity emits gas and particle pollutants from motor vehicles, construction, industry, power plants, and peri-urban mining. Sulfur dioxide (SO_2) and oxides of nitrogen (NOx) are eye irritant, trigger respiratory diseases, cause acid rain, and damage construction materials, vegetation and water bodies. Lead reduces cognitive capacity in children. Fine dust particles of 0.1 to 25 micrometers in diameter cause respiratory diseases and are carcinogens. Carbon monoxide is toxic in high doses. Dioxins and volatile organic compounds like methane and benzene are carcinogen; and ozone is known as a photochemical smog agent (Grant 2012). Deficient air quality in urban areas is a major public health issue that causes premature deaths and has significant economic consequences: the expenditure in health issues due to air pollution accounts for 2% of the growth domestic product in developed countries and 5% in developing countries.

Urban activity generates other forms of pollution related to perception: Noise and artificial light. Construction activities, industry, transportation and leisure facilities are the main sources of noise in cities, which cause negative psychological and physiological impacts on humans: hearing capacity loss, heart issues, stress and gastro-intestinal deficiencies. Light pollution is related to breast cancer, increases fatigue, minimizes visual capacity and produces anxiety and stress (Grant 2012). These two environmental disservices are also known as major disruptors of wildlife.

In terms of metabolism, cities consume resources and environmental services produced somewhere. They demand large quantities of food, materials and energy. As urban systems do not run on close loops of materials and energy, great amounts of waste are generated. Most of organic, construction and industrial residues are disposed in landfills that often threat human health. Waste is a mayor byproduct of cities. In many cities that lack effective waste management schemes, debris, industrial and biological trash are dumped in public spaces or natural areas affected by chronic contamination of soil and watercourses. As a consequence of the inefficient urban metabolism, city dwellers have a greater ecological footprint than their rural counterparts, which creates high ecological pressure on the non-urban ecosystems where resources are taken from. Unless we manage to create and maintain self-sufficient and multi-functional cities capable of producing environmental value, the world's ecological footprint is to increase in the coming decades.

Urbanization and sustainability: opposite shores?

The idea of urban environmental services is essential to transfer well-being concerns from the global scale to the urban context. Several authors have linked urban environmental services to the notion of urban quality of life (Breuste, Haase et al. 2013), (Santos, L.D. and Martins, I. 2007). Breuste et all relate the ecological dimension of sustainability to environmental services by stressing the need to maintain healthy environments that provide "clean air, protection against respiratory diseases, protection against heat and cold death". Well-being is related to qualities of the ambient environment on several environmental factors: air, water, temperature regulation and waste processing.

Although only 3% of the surface of the planet is occupied by cities, these areas account for 2/3 of the world´s energy consumption and 3/4 of the global greenhouse emissions. By 2030, more that 60% of the world population will live in cities. This will increase the demand for services and make available ecoproductive land scarcer. It is widely assumed that in cities the sources of the environmental services are natural or semi-¬natural land-based assets such as parks, trees or wetlands.

"Cities rely on ecosystem services in the wider world, but it is important to remember that ecosystem services can be provided within the city by creating multifunctional, biodiverse, green infrastructure to complement (and wherever

possible reduce or replace) gray infrastructure." (Grant 2012).

The fabric of existing and new buildings that make most of the land cover in urban areas is seldom considered a source of environmental contributions. The knowledge needed to conceive buildings and sites as ecoproductive settings has remained apart in different fields. Whereas the green building field still focuses on developing efficiency to reduce energy consumption, cut down carbon emissions and minimize the ecological footprint; the environmental sciences have not studied other sources of environmental services in depth beyond natural land covers or natural ecosystems´ components. This field divide has created a dichotomy between environmentalist and developers, which often slow down city planning processes around areas with environmental controversy. If architects and urban planners integrate knowledge and methods from the environmental sciences to participate in the production of environmental value, cities would have an opportunity to restore the ecocapacity of the urban land, and involve private actors in this endeavor of great public interest.

From an environmental perspective, cities are like deserts or spaceships. In deserts, vegetation and biodiversity must be inserted to support life. In spaceships, environmental services must be engineered. Can buildings and sites integrate nature or engineer environmental services to augment the overall health of cities, self-sufficiency and urban multi-functionality?

3. THERE IS MORE TO SUSTAINABILITY THAN REDUCING NEGATIVE IMPACTS

Recent scientific reports on the current world's environmental state suggest that even though mitigation of negative environmental impacts caused by human activities is a significant advance, it is no longer enough to tackle the current environmental overshoot unbalance. Several authors support this idea, premised on the argument that the environmental debt threshold of human activities has already been trespassed and the environmental decline is now irreversible (Lovelock 2009). Emerging paradigms beyond "sustainable" development and recent global publications on the world's ecosystems integrity imply that minimizing the negative impacts of human activities is not enough anymore, as well-being depends on the health of ecosystems and the environmental contributions they provide.

Sustainable development as an aspiration is about allowing future generations to satisfy their needs. However, this concept has failed to tell us how we can achieve such goal. Most of the practical applications of sustainable development are translated into initiatives that are aimed to reduce negative impacts: saving energy, not using too much plastic, reducing the ecological footprint, and such. These strategies are indeed good and necessary, but fall short on the demanding challenges that human growing population face, which calls for more urgent and drastic actions leading us to restoration of the earth's ecocapacity. The so-called "sustainable" practices in the architecture arena become insufficient in our present time. When the aspiration of restoration is transferred to architecture, buildings appear as a 3D fabric that can afford to create, embody and interface eco-services in their urban surroundings.

4. THE OVERSIGHT OF "SUSTAINABLE" ARCHITECTURE

Oversight:

1. Watchful and responsible care. Regulatory supervision.

2. An inadvertent omission or error.

Milestone publications have fostered environmental awareness; and in its turn, triggered "sustainable" responses in different disciplines. In architecture, most of such response has been manifested through the "eco-technic" green building approach widely adopted "based on a techno rational, policy-oriented discourse". The "ecological modernization paradigm derived from here centers the attention over distant global environmental problems like climate change and CO_2 emissions" (Guy and Farmer, 2001) (Reed 2009) (Cole 2012).

In recent years, an emerging body of criticism has argued that the prevailing "sustainable" architecture approach is necessary but incomplete. A number of authors have identified key shortcomings attributed to the most widespread green building assessment tools:

- "Green" building assessment tools focus on mitigation of negative environmental impacts. Consequently, they lack criteria and methods to assess positive impacts of buildings on their local environments, (Meng and Run-ming, 2009). Other authors have also addressed this omission and reacted by highlighting the need to conceive "green building" as a means to produce positive impacts on the environment (McDonough and Braungart, 2002), (Olgyay and Herdt, 2004) (Birkeland, 2008), (Reed, 2009).

- Green building assessment tools lack consideration of the operational integration of architecture with their immediate environment. Exploration on ecoproductive architecture implies finding ways of advancing the ad hoc functional integration of sites and buildings with the local natural ecosystems (Lyle, 1994) (Meng and Run-ming 2009).

5. THE HUMAN ROLE IN THE META-HUMAN WORLD

Anthropocentric mentality has underestimated the importance of non-human forms of life. In

Figure 1. Current urbanization problematique and gaps of the widespread green building approaches. AIG

ENVIRONMENTAL CONTRIBUTIONS RELATED TO ECOSYSTEM SERVICES AND GOODS		MEA, 2005 Supporting	MEA, 2005 Provisioning	MEA, 2005 Regulating	Costanza et al. 1997	Daily, 1997
AIR	Gas Regulation				x	
	Production of Oxygen Gas thought photosynthesis	x				
	Purification of air - Air quality maintenance			x		x
CLIMATE	Climate regulation			x	x	
	Disturbance regulation				x	
	Mitigation of Floods and droughts					x
	Partial stabilization of climate					x
	Moderation of temperature extremes and the force of winds and waves					x
WATER	Water regulation			x	x	
	Water Cycling	x				
	Water Purification			x		x
	Water supply		x		x	
SOIL	Erosion Control and Sediment retention	x		x	x	
	Soil formation	x			x	
	Generation and renewal of soil and soil fertility					x
NUTRIENT CYCLING	Nutrient cycling	x			x	
	Primary production	x				
	Waste treatment – Management			x	x	
	Detoxification and decomposition of wastes					x
	Dispersal of seeds and translocation of nutrients					x
BIOLOGICAL	Regulation of Human Diseases			x		
	Pollination			x	x	x
	Biological Control			x	x	
	Refugia and provisioning of Habitat	x			x	
	Maintenance of biodiversity					x
FOOD AND FIBER	Food, Fiber Production		x		x	
ENERGY	Fuel wood		x			
MATERIALS/ GOODS	Raw Materials - Medicines - ornamental resources		x		x	
GENETIC	Genetic Resources and Information		x		x	

Figure 2. Environmental services or nature's contributions listed by milestone publications

the present time, posthumanism's ideas gain relevancy as the environmental crisis strongly conditions our political, economic and social systems, and algorithms gain more influence over our daily lives. Meta-human perspectives call for changes in the way humankind relate to other forms of life, supported on the idea that we should conceive all biotic organisms and artificial non-conscious intelligence as crucial to shape reality as we are. This perspective beyond human-centered world is reflected on to practical cases. A river recently won a legal battle against polluters in Colombia and another in New Zealand, after high courts recognized the rivers' rights as individuals. In New York and other financial centers, investors have reported great losses due to the advantage of algorithms over humans on data processing capabilities that lead to better decision-making. Courts and legal authorities are studying the possibility of processing lawsuits against algorithms, and according to experts, this might become a common practice in the coming years.

Under the meta-human worldview, nature and technology is no longer a divide. In the technosphere, nature is defined by the set of organisms and systems in the overall artificial-natural gradient (thenextnature.org). This network is animated by interaction or information. To tackle the current and future environmental imbalance, humans should play a restorative and ecoproductive role: restorative so that the capacity of the ecosystems to support life and maintain functional balance is recovered, and ecoproductive so that the man-made world affords to enhance the overall healthy human and non-human environment conducive to integrity of all forms of life. Under this scenario, intelligence is redefined as the capacity of an organism to improve its integrity by positively impacting integrity of the environment it belongs to, rather than acting as a discrete part of the ecosystem. This suggests that to achieve ecoincremental cities, smart architecture should embrace ecoproductivity.

6. SUBSTANTIVE SUSTAINABLE DEVELOPMENT THROUGH ECOPRODUCTIVITY

Three influential world scientific reports (WRI 2005) (TEEB 2011) (WWF, London et al. 2010) have evidenced the global environmental facts that push the capabilities of “green” architecture beyond the paradigm of sustainable development as it has been understood in the last four decades. Both publications pictured how “progress” has seriously compromised human well-being in the last century, and will continue to do so given the depletion of natural resources and alteration of the ecosystems’ functionality. The Millennium Ecosystem Assessment (MEA) brings the concept of ecosystem services (or nature’s environmental contributions) as the most important issue for human development. According to MEA, 65% of the earth’s ecosystems are in decadence, which creates a serious deficit of environmental services needed for well-being. It is estimated that two planets would be required by 2030 to generate enough environmental capacity that sustains the current model of human development and urbanization rate.

The MEA defines ecosystem services as the “benefits people obtain from ecosystems”. These services are classified into 1) provisioning services –e.g. materials and energy-; 2) regulating services –e.g. climate regulation and air purification-; 3) cultural services related to intangible human needs such recreation; and 4) supporting services which are fundamental natural processes necessary for all other services –e.g. photosynthesis, soil formation and nutrient cycling (Hester and Harrison 2010). According to MEA, human demand for resources will grow greater in the coming decades. A number of authors have shown that the demand for environmental contributions is now so significant that their valuation and trade-off will be common practices (Gomez-Baggethun, de Groot et al. 2010), (Bastian, Haase et al. 2011), (Sagoff 2011), (Wegner and Pascual 2011).

The key merit of the MEA and the Living Planet Report 2010 is the adoption of a comprehensive framework of environmental contributions that covers the key environmental concerns of previous decades with the same umbrella: energy crisis, resources scarcity, global warming, CO_2, and carrying capacity. Under this holistic perspective, substantive sustainability is about augmenting the four categories of environmental services required for human well-being (WRI 2005) while natural ecosystems´ integrity is restored and preserved. In Urban settings, this implies restoring the ecocapacity of the territory that was depleted during the urbanization process.

What is ecoproductivity? It is defined here as the capacity of a physical entity, either natural or artificial, to generate contributions on its surroundings so that integrity of the environment is improved. Efficiency in ecoproductivity is determined by the ratio between the input resources and the output contributions. Spatial efficiency of ecoproductivity is determined by the ratio between the physical boundary of the source and the rate of production of services in a given timeframe. Environmental sciences relate urban parks, forests, green belts and trees to environmental quality and recognize these natural components as sources of environmental services (Sandhu and Wratten 2013). Under this perspective, natural elements are key to maintain urban environmental quality and well-being.

In 1997, Costanza suggested that ecosystem services couldn't be replaced with technology. However, more recent publications suggest that little attention has been given to man-made ecosystems like farmlands and cities as settings that can afford to create ecoproductive outcomes.

"Although the concepts developed have evolved from experience managing natural assets in rural landscapes, these ideas are equally applicable to urban and other predominantly cultural systems. " (Wallace 2007).

For Palmer et al., 2004, engineered or modified ecosystems are both providers and consumers of ecosystems. "They can provide a wide range of important environmental services".

The concept of ecoproductivity seems to trespass the boundaries of the natural sciences and find a place in the material world of biotic and abiotic elements created and managed by men. The environmental contributions produced by objects, buildings or sites are a feature that has not been studied in depth. Environmentally speaking, nature has been considered as a provider, and buildings as takers. This long-standing role dichotomy between natural and man-made environment is to be blurred in the coming decades, as the array of technologies, buildings and manufactured landscapes capable of creating environmental contributions expands.

7. ENVIRONMENTAL CONTRIBUTIONS AS A RAISON D'ÊTRE OF ARCHITECTURE

Building footprint replaces the capability of the natural terrain to produce ecosystem services with capability of the building to produce building services. But can architecture afford ecoproductivity? The core attributes of architecture introduced by Vitruvius are considered valid here to define the boundaries of architectural practice: architecture has the ultimate goal of creating building services related to three aspects: Function, Structure and Aesthetics (Vitruvius 2003). The principles and strategies of "green" and "sustainable" buildings are supplementary measures intended to counterbalance negative environmental impacts. This does not reflect an additional core attribute of architecture, but rather a way of counteracting an undesirable byproduct of the essential attributes of architecture proposed by Vitruvius.

In recent years, a small number of scholars and practitioners or architecture have started to investigate how buildings and sites produce environmental contributions, but there are conceptual and pragmatic implications that remain unexplored.

Ecoproductivity as an intrinsic attribute of architecture. Definitions.

If MEA's concerns are transferred to architecture, substantive "sustainable" development should be targeted via buildings that not only preserve ecosystems but also create and deliver environmental contributions. However, ambiguities and problems with the use of this concept have been reported in multiple disciplines (Wallace

2007). Wallace's work suggests the need to use proper definitions to avoid confusion and misleading classifications.

Wallace's definition of ecosystem –and ecosystem services- encompasses biotic but also abiotic elements (culturally derived), such as domestic animals, buildings, roads and humans themselves (this is also supported by the MEA). However, he has shown that in most of the literature "the term ecosystem –and ecosystem services- is used in a way that implies only the natural elements of ecosystems". Pedersen Zari, who has explored the application of ecosystem framework in the field of architectural design, uses the term ecosystem services to refer to both environmental services that are either produced by biotic elements assembled on buildings, and environmental services engineered (Pedersen Zari 2012). However, following previous key Wallace's concerns, further lexicon development is necessary to differentiate environmental services that are produced by nature from those produced via buildings, either by integrating biotic elements or incorporating ecoproductive technologies.

Although the MEA classifies ecosystem services according to type and core environmental aspect, it makes no distinction or classification relative to the sources of the services. Under MEA's optics, all sources (either natural or anthropogenic) are indistinct. However, there are three main reasons to consider such distinction necessary and beneficial. First, in very recent years, a number of engineered technologies have been proven to create and deliver environmental contributions. Second, trade-off and schemes of co-benefits in urban planning regulations make it necessary to differentiate environmental services delivered by natural or semi-natural elements –i.e. street trees- from those created by architecture or man-made infrastructure projects. And last, such distinction contributes to the appropriation of ecoproductivity as a core aspect of architecture.

In Vitruvius triad, building services are created by the intrinsic qualities of firmitas, utilitas y venustas. If production of environmental services is added as a core attribute of architecture, ecoproductivity arises as a fourth dimension. The appellative "Ecoproductive" is proposed and used to refer to architecture that is aimed to create environmental contributions in addition to the delivery of building services. The term "ecotectural contributions" is introduced to address the environmental value created by ecoproductive architecture, and to differentiate them from those produced by natural ecosystems.

In the built environment field, eco-productivity is an inherent spatial attribute e as it is the capability of the sites and buildings to generate environmental services at a certain rate within given physical boundaries. Humans are part of ecosystems and together comprise a whole (Lyle 1985). However, there are significant differences in the way undisturbed natural systems produce environmental services compared to 1) natural systems altered by humans, 2) semi-artificial settings managed by humans, and 3) artificial settings.

The level of human influence on the ecosystem is key for classification. The diagram shown in Figure 3 clarifies the proposed terminology. "Environmental Contribution" is used as the

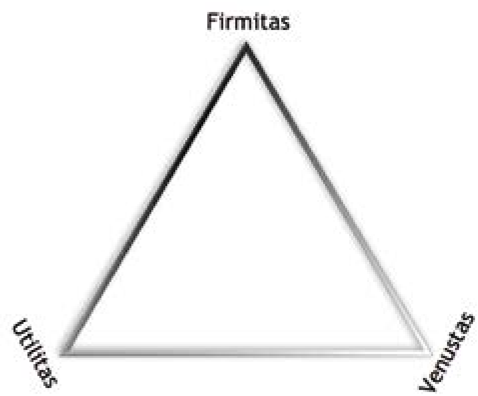


Figure 3. The Vitruvian triad historically defined the core attributes of architecture

most generic term. It comprises all kinds of environmental services, created by either undisturbed natural sources or man-influenced settings. "Natural Ecosystem services" are environmental services created by undisturbed nature. "Ecotectural services" are produced within the boundaries o man-made spatial settings -buildings or infrastructure-. Hence, the following affirmations are considered useful:

• The group of "environmental contributions" encompasses all "natural" and "ecotectural" contributions, produced by either man independent or man-influenced settings. In other words, all ecotectural and nature's contributions are environmental contributions.

• "Nature´s contributions" are produced mainly by man-independent settings –undisturbed nature-. However, as humans are part of ecosystems, man influenced settings involving biotic assets are also considered sources of ecosystem services (e.g. urban parks, biotic roofs, etc). Environmental contributions produced by artificial abiotic technologies do not belong to the group of ecosystem services or nature's contributions.

• "Ecotectural contributions" are environmental contributions produced by man-made settings, and might encompass biotic elements or/and technology. Not all ecotectural contributions belong to the group of natural contributions. Not all environmental contributions are ecotectural services.

Architecture can produce ecotectural contributions on multiple functions that relate to the overall functional integrity of cities.

8. ECOPRODUCTIVE ARCHITECTURE IS MULTI-FUNCTIONAL. A CASE STUDY IN BERLIN

The UfaFabrik International Culture Center is located in Berlin. It was a former UFA-Film factory originally built in 1920 and used as a copy center for German film studios. Today, it supports young modern culture and combines international and local cultures to create a dynamic atmosphere for active people (www.UfaFabrik.de/en). The site consists of 6 main low-rise buildings, gardens, and other amenities, which were designed and built by a group of local entrepreneurs to enhance the environmental conditions of the site and reduce operational costs (Figure 4). Since the decade of 1970s, they developed and progressively integrated a series of technologies on the buildings and site. Most of them pioneered aspects of green building in Berlin at the time of implementation i.e. the biggest solar roof, the first water harvesting and natural treatment system on a wetland roof, the first pilot implementation of slotted wind turbine, and an unusual biodiverse vegetated roof.

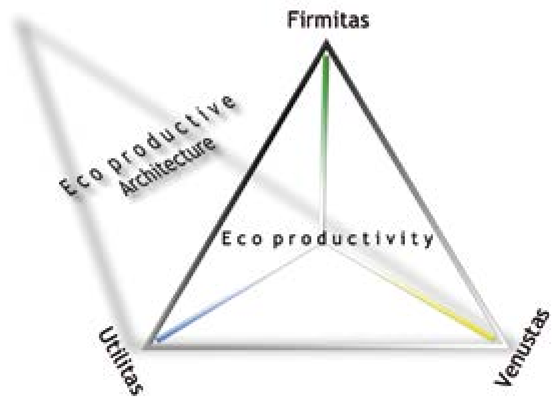


Figure 4. Proposed dimension of ecoproductivity as a core attribute of architecture, based on the Vitruvian triad. AIG

This case is a valuable piece of evidence to study multifunctional ecoproductivity in architecture, given its innovative character, early implementation, and integrative approach. The ecoproductive performance of the center encompasses multiple strategies that create three types of contributions on a number of environmental aspects.

Provisioning services

The center produces clean energy and food. Direct solar radiation is converted into electricity by two kinds of photovoltaic systems. Fixed photovoltaic panels were installed on the roof of two buildings in 1997 to generate 50 kWh (Buildings 4 and 5). Three years later, an additional system was installed in one of the building to include 10 2kW automated PV system that included cells, inverters and sun tracking sensors (Building 1). The overall capacity of the two systems (peak) is 70 kWh; enough to feed the total center demand and sell the surplus energy to the grid (Figure 5). After reviewing the records from 2003 to 2012, an annual energy generation average of 39850 kWh was estimated. This means an annual reduction of about 36 tons of carbon dioxide emitted to the atmosphere. However, only the clean energy generation aspect is considered here as an ecotectural contribution. Wind is also used as a source of energy. In 1995, a 3-meter high rotor wind generator was installed on the roof of the former "film bunker" (Building 6), to provide a generation capacity of 700 Watt. A further addition assisted by TU Berlin was implemented to increase this capacity by 20% with a slotted rotor design that was tested in the wind tunnel (Patent by Achmed Khammas). Food is produced in the form of herbs that are grown on the roofs and gardens (alfalfa, hops and kidney vetch).

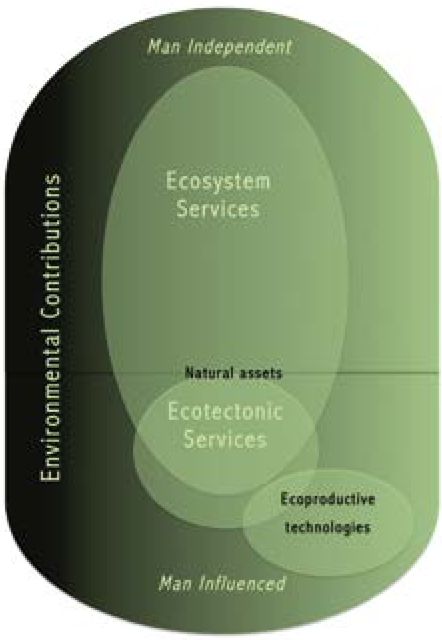


Figure 5. Proposed classification of environmental contributions relative to their source. AIG

The center incorporates a rainwater management system that provides various environmental contributions related to water: harvest, treatment and reduction of water run-off to alleviate and prevent overflow of sewer systems (Schmidt, 2001). In 1994, a rainwater harvesting system was integrated to provide water for irrigation and toilets. The roofs and ground landscape account for a total area of 7600 m2 that catches rainwater. The water harvested is conducted to and stored into two 240 m3 underground cisterns (equivalent to 39 mm or 6.7% of annual rainfall). It is then treated naturally, pumped and distributed through the building to meet the overall demand of water, which was estimated at 3000 m^3 per year. 72% of the water used for flushing the toilets and irrigating the green areas comes from the water harvesting and treatment systems.

Regulating services

The center produces regulating environmental contributions related to water, air, climate and nutrients cycle. The rainwater collected is treated naturally by a constructed wetland that is the roof of two underground cisterns (25 m^2). In the first cistern, particles such rocks, sand and mud are settled in the bottom. When water flows into the second tank, floating elements such leaves paper and wood are trapped by a gravel wall. The partially treated water is then stored and pumped up onto a gravel and microorganism media that removes the remaining suspended solids and converts impurities into minerals that are absorbed by reeds, rushes, water lilies and cattails. Heavy metals and nutrients are captured by the wetland and reduced by 90% (Schmidt, 2001). This process prevents pollutants from running off into rivers and streams.

Evaporation and evapotranspiration are the main UfaFabrik's environmental contributions related to climate regulation. The outcome of this energy consumption is temperature reduction (evaporative cooling). The amount of solar energy required for the evapotranspiration of 1g of water is estimated at about 2450 joules. Daily radiation balance estimations were made based on measurements conducted by Schmidt at UfaFabrik during the summer of 2000. Bitumen and green roof scenarios were compared under a 5354 Wh/m^2 daily solar available energy scenario. A significant reduction of latent heat emitted by green roofs was found, in comparison with bitumen roofs. The bitumen surfaces converted 2.29% of the solar available energy into evaporative cooling, 34.1% into latent heat, and 9% was reflected. In contrast, results for vegetated surfaces were 22.13%, 16.28% and 14.99%. After observations conducted from 1987 to 1989, the green roof cooling rate mean per year was estimated at 302 kWh (/m2*a) (C. Centegraf and Schmidt, 2005), and the effective evapotranspiration mean was estimated at 443 mm out of 696 mm local evapotranspiration potential and 588 mm local precipitation mean (Schmidt, 2005).

Services related to nutrients cycle are produced in UfaFabrik mainly through the use of fast composters specially designed. Besides the widespread waste collection and separation schemes, organic waste is processed at UfaFabrik to produce organic fertilizer. The waste produced by the center is estimated to be 1000 m^3 per year. Approximately 20% of it can be composted (about 200 m^3 per year). Two 1 m^3 spinning wooden composting drums were built. They speed up the process by providing a constant alternation of heat and oxygen and allowing regulation of humidity levels. With this system, the center has a capacity of producing about 1 m3 of compost per month (at the moment of the study). Air regulation contributions are linked to removal of pollutants and enhancement of the air quality. Field measurements with two carbon dioxide probes were conducted to determine the concentration of CO_2 on the air above a green roof in comparison with a gravel roof. Maintaining the same wind conditions, available solar radiation levels and temperature, the air above the vegetated surface showed a reduction of 18% in carbon dioxide concentration levels compared to the hard surface during the day time in summer. Considering that the oxygen emission capacity of an extensive green roof is estimated in approximately 400 liters per day, the overall daily oxygen production capability of the vegetated surfaces of UfaFabrik would be 480 m3. Labs tests and microscopic analysis were conducted to determine the dust retention capacity of different vegetation types. Results showed that sedum retains more PM10 particles than grass. It has been estimated that the average dust retention capacity of an extensive green roof with similar characteristics to those of UfaFabrik is 500 gr per square meter per year. Thus, the green roofs and vertical gardens of UfaFabrik would approximately capture up to 700 kg of particulate matter from the ambient air per year.

Other regulating services produced are noise and smell absorption. Kitchen exhaust fumes are conducted towards to a gravel filter under a green roof, allowing plants and media to absorb the gases. Users of the center reported reduction of smell from the kitchen. A vertical garden was built to prevent noise discomfort caused by the cultural activities in the neighborhood. The total approximate area of green roofs in the center at the moment of the study was 1500 m^2. The original roof finish consisted of a tar-and-asphalt waterproof layer. In 1980 some of these surfaces begun to be retrofitted to support native grasses, herbs and perennials with conventional multilayered extensive green roof systems comprised of a substrate mixture of soil and expanded

Figure 6. UfaFabrik location in Berlin (retrieved from google maps), and overall site retrofit image

clay. The vegetation population has shown a significant variation and adaptation to different microclimate and maintenance conditions. Regular irrigation was only provided during the early years of the installation, which favored clovers and draught-tolerant species. Currently, however, the landscape and plant population is totally different from the initial conditions.

Dr. Manfred Köhler has been studying the evolution of the roof vegetation in the long term, and has identified about 50 species. During the field investigation with Dr. Köhler, we noted that variations in the depth of the substrate in later installations could motivate the unusual biodiversity of the roofs in spite the fact that most green roofs in Berlin have sedum as the predominant type of plant

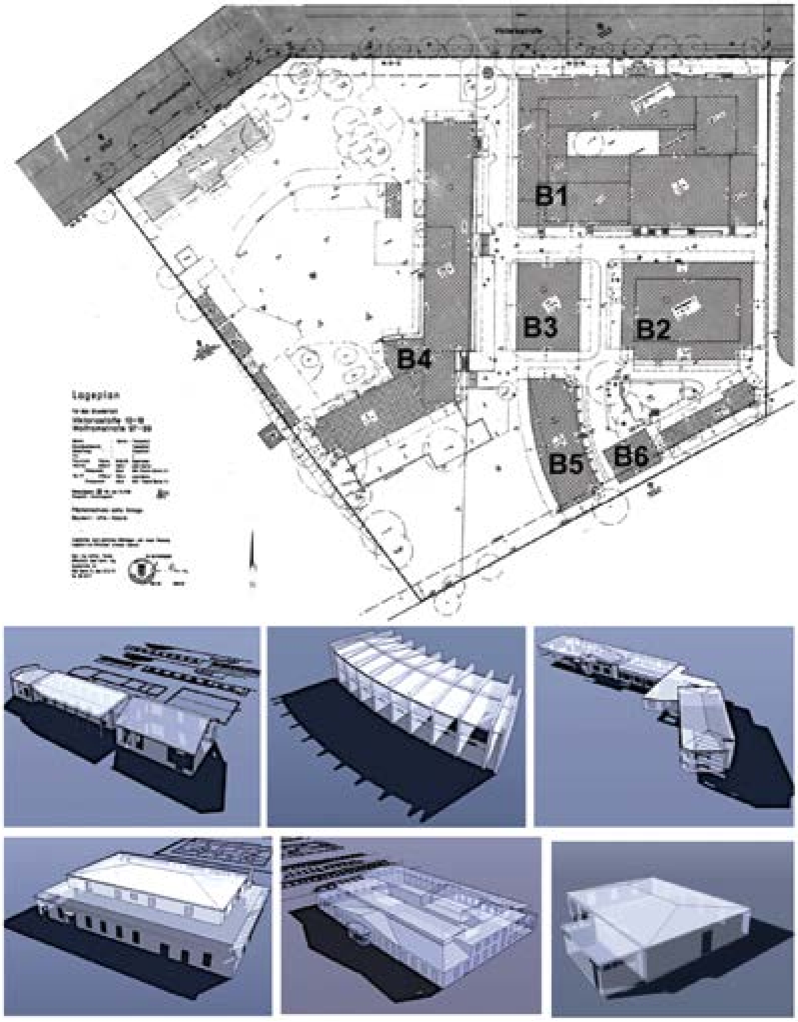


Figure 7. UfaFabrik's site plan and buildings. 3D models: AIG

(Building 4) (Figure 6). Particular conditions motivated this adaptation. For example, taller low-light species colonized the area under the photovoltaic panels, as they provide protection from the wind and sun i.e. Sagebrush and gray cress. Today, sedum accounts for only 50% of the green roof. Steel wire was attached to the facades, and various climbers were planted at the ground level. As a result, each vertical wall shows a particular prevailing type of plant, according to the sunlight availability and solar exposure conditions. The wild ones covered the southeast side of building 5, whereas hydrangea and clematis and ivy colonized the south, north and west sides of the exhibition building. These species provide habitat for wildlife and foster biodiversity in the neighborhood. The absence of human intervention in the distribution of the species over time has turned these roofs into valuable evidence to study plant adaptation in Berlin.

The diagram of Figure 8 shows the overall UfaFabrik site's ecoproductity, by relating the different technologies investigated to the ecotectural contributions they create. The overall functional domain analysis evidences that although the engineered technologies used can afford single ecoproductive outcomes like provision of clean energy, the biotic elements

Figure 8. Clean energy generation at UfaFabrik. Photos: AIG

are more synergistic, as they create several environmental contributions simultaneously (grey dotted and hyphened lines).

Visualization of multifunctional ecoproductivity

Two kinds of radar diagrams were developed to visualize the overall multifunctionality of sites and buildings, as well as their annual production rates (Figure 7). The number of single environmental contributions to estimate determines the number of axes in the radars. Estimation of yearly production is done using the right units for each contribution; for example, m^3 is used for rainwater harvesting, and Tons is used for CO_2 capture. Results are marked on the axes. The center of the diagram represents a value of zero. The greater the production rate, the more distant from the center the markings are located. Each axis can have independent ranges of values depending on the maximum value. If the single markings of each contribution are connected with lines, the area of the resulting polygon represents the overall ecoproductivity. Through this method, it is possible to evaluate the integrated performance of a specific site or building relative to the ecoproductivity of different land covers and scales presented as assessment baselines in the next section.

9. MULTI-SCALE ASSESSMENT OF ECOPRODUCTIVE BUILDINGS AND SITES IN URBAN SETTINGS

Urban architecture's ecoproductivity is fundamentally a multi-scale phenomenon. It encompasses physical forms, devices, buildings and cities. They are all different levels in which production of ecotectural contributions happens. Thus, a comprehensive assessment framework of site and building ecoproductivity should necessarily address these scales and enquire on how environmental contributions are produced, delivered and valued accordingly.

Lets illustrate multi-scale ecoproductivity assessment using the example of a bicycle as an analogy to a building. A bicycle's inherent purpose is transportation. However, if a water purification system is integrated, polluted water can be converted into potable water as the rider pedals. Polluted water is sent out of a rear tank through a series of filters, and collected in a front tank once it has been purified. A new intrinsic attribute has been added to the bicycle: the capacity to provide clean water. This emerging attribute is intrinsic because it is linked to the essential function of the bicycle. Both purposes, transportation and water purification, are now part of the same functional domain. The bicycle now has an added value, and it is manifested in an increment of the bikers' wellbeing resulting from access to clean water.

The service of water purification happens here in three physical scales from small to large (or simple to complex): the purification devices, the whole bicycle including the purification system, and the place where the bicycle is used. Thus, to assess the bicycle's merits for purifying water, this service must be measured in reference to 1) the devices, 2) the bicycle and 3) the place. Or in other words this service must be unfolded, embodied and interfaced.

Unfolding water purification is calculating how much water (volume) the filters can purify and the tanks hold per each kilometer pedaled. Unfolding is objectively translating physical forms directly responsible for creating an environmental service into production rates expressed in units associated to that service. Embodying water purification has to do with assessing the spatial efficiency of the whole bicycle to produce the service, in reference to its size and form. That is, how space-efficient the filters are, occupying minimum space, avoiding overweight or even enhancing the function of the bicycle. From here it can be

Figure 9. Composting devices at UfaFabrik site. Photo: AIG

Figure 10. Tests with carbon probes to determine the CO_2 concentration of the air above the green roofs. Photos: AIG

inferred that the better the purification system fits within the bicycle's psychical boundaries, the greater the amount of clean water that could by delivered per spatial unit. And lastly, interfacing water purification is related to the need and appreciation of bikers for clean water. This is conditioned by the availability of clean water in the bikers' town, and its perceived value. In other words, interfacing is about weighting up the value of a given environmental service, in reference to a specific place. The more value given to clean water in a particular locality, the higher the bicycle's merits are.

Lets imagine that the bicycle simultaneously provides additional environmental contributions: captures air pollutants, produces energy, and cools down the rider. The bicycle's environmental value would eventually increase, and all delivered services would need to be unfolded, embodied and interfaced to assess the overall ecoproductivity.

Transferred to the architectural field, ecoproductivity assessment entails three kinds of assessment: estimation of production rate (at the technology scale), spatial integration (at the building scale) and instrumental valuation (at the urban scale). Although these methods have not used for building assessment, there are a number of disciplines that have used them. Assessment related to technology's ecoproductivity rates is commonly done in engineering, material science and technology development fields; spatial integration assessment is associated with landscape, green infrastructure, ecology and natural sciences; and instrumental valuation has been explored in the fields of urban ecology, green infrastructure, geography, economy and town planning. Combination of these approaches and techniques is needed to formulate comprehensive frameworks applicable to urban architecture that could be instrumental to town planning trade-off schemes.

Figure 11. Adaptation of roof and living walls plant populations to particular environmental situations. Photos: AIG

10. PROPOSED LAEBS METHOD FOR ASSESSMENT ECOPRODUCTIVE BUILDINGS AND SITES

What is ecoincremental city planning? It is town planning and urban design that aims to increase the capacity of the existing cities to generate environmental. This encompasses conservation of urban and peri-urban undisturbed nature, restoration of local ecosystems, and urban greening; but it also engages the universe of users, stakeholders and actors who design sites and buildings in the goal of achieving ecoproductive and restorative cities.

Imagine a developer or group of building owners who participate in this endeavor. Their site and building is capable of producing oxygen, capturing CO_2, reducing the run-off water that goes into the urban water evacuation system, minimizing the flood risk, absorbing noise, creating natural habitat for local flora and fauna, combating global warming, and increasing the available area for people's enjoyment. Imagine that for creating these environmental contributions of public interest, developers and owners receive urban planning incentives, and city administrations reduce expenditures on infrastructure, environmental calamities and health-related issues. Ecoproductive architecture functionally integrates itself to the network of natural and semi-natural urban areas. This is solution of high value for society because it is the most efficient way to improve the environmental quality of cities without the need of empty available land, which is growing scarcer. When nature and ecoproductive technologies are incorporated into sites and buildings, a win-win situation for privates, citizens and public authorities is created. This co-beneficial approach is key to the participative production of restorative and multi-functional cities. Assessment of urban environmental contributions by ecoproductive sites and buildings is central to co-benefits and town planning trade-offs.

The LAEBS method proposed here enables designers and policy makers to assess the capacity of a site or infrastructure project to generate environmental contributions by estimating the annual rates at which a number of these services are created per unit of land in comparison to 4 local baseline scenarios at different scales: 1) pre-existing conditions, 2) overall metropolitan area, 3) neighborhood planning unit, and 4) a local undisturbed ecosystem. LAEBS stands for Land Average Ecorproductive Baseline at different Scales.

Each baseline provides a scale-driven reference for ecoincremental urban planning to know if a site or building exceeds the annual environmental contributions production rates. Different time and surface units can be used to estimate the ecoproductivity of each baseline case. Year and hectare are units that facilitate the evaluation for urban planning and trade-offs applications. To compare results, an average hectare is considered for the project under assessment, as well as for each baseline. This is shown in Figure 10, which set the 4 baselines for particular project designs in the city of Bogota.

Figure 11 shows the application of this tool in the design of a 120-house residential complex in the city of Cali, Colombia, by UNOA design team. The project is designed to create a number of environmental services related to water, air, energy, food, climate and materials. The radar visualization evidences that the project exceeds the rate and efficiency in generation of a number of environmental contributions per hectare, in comparison to the overall Cali's performance.

The method leads to further development of ecoproductivity indexes associated to each baseline. As an example, for the baseline 3, an index higher than 1 means that the project improves the existing conditions of the whole neighborhood. An index of 1 or above in the baseline 4, an undisturbed natural ecosystem, would be the greatest aspiration for restoring the ecoproductivity of the city.

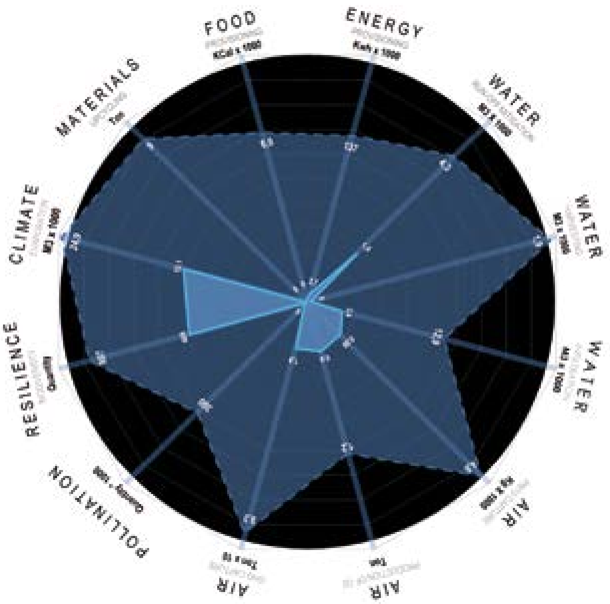


Figure 12. Radar diagram developed to visualize the overall ecoproductivity of a site or building. This particular diagram shows the annual overall ecoproductivity of a building designed in Bogota city (outer polygon) in comparison to ecoproductivity of the preexisting site conditions (inner polygon). AIG

11. THE ROAD AHEAD: TRANSFERRING NATURE´S PRINCIPLES TO ECOPRODUCTIVE DESIGN

3.5 billions of evolution has turned nature into the ultimate ecoproductive and ecoincremental system. Living and organisms have adapted to complex environments, creating balanced networks that support life, diversity and abundance. In natural ecosystems, there is no need to reduce negative impacts, as every organism has developed strategies and functions that are beneficial for other organisms and their surroundings. Nature's forms, processes and ecosystems are the largest source of human inspiration for technologies and man-made environments aiming to generate environmental contributions. It is estimated that in the coming decade, nature inspired innovations will account for 15% of the economic growth in the architecture and construction sectors.

Colombia is the most biodiverse country per land surface, which provides vast opportunities for learning from nature's functional principles and advancing architecture from an ecoproductivity perspective. Although the practice of biomimicry is not common in the region, the Ecoincremental Lab in Bogota has been creating ecoproductive designs over the last two years.

Cactar is a bio-inspired building façade system that applies the principle of cellular transition for generating energy, harvesting water from the ambient air, growing food, and cooling down the urban climate. After observing the nanostructure of local cactae spines under the scanning electron microscope, the design team found that the cells changed their form and structural configuration along the spine to perform different functions. The cells stemming from the cactus are set in a tridimensional mesh that allows the exchange of fluids. This configuration changes, as the cells get closer to the tip of the spine, where a dense laminated grouping patter was found to provide material strength and physical protection to the cactus.

This progressive change in geometry and grouping pattern was used to create a structure that can be assembled on existing buildings facades. The upper section of Cactar's core structure incorporates PV systems that generate energy and catch rainwater, the mid section creates chambers for plants growth, and the bottom part provides structural resistance via laminated elements. A light mesh made of plant fibers covers this core structure and cause a temperature differential to force the dew point, which allows condensation to happen. Condensed water falls onto the core and is collected at the lower section of the structure.

Evapost was designed as an urban micro-infrastructure piece that functions as street

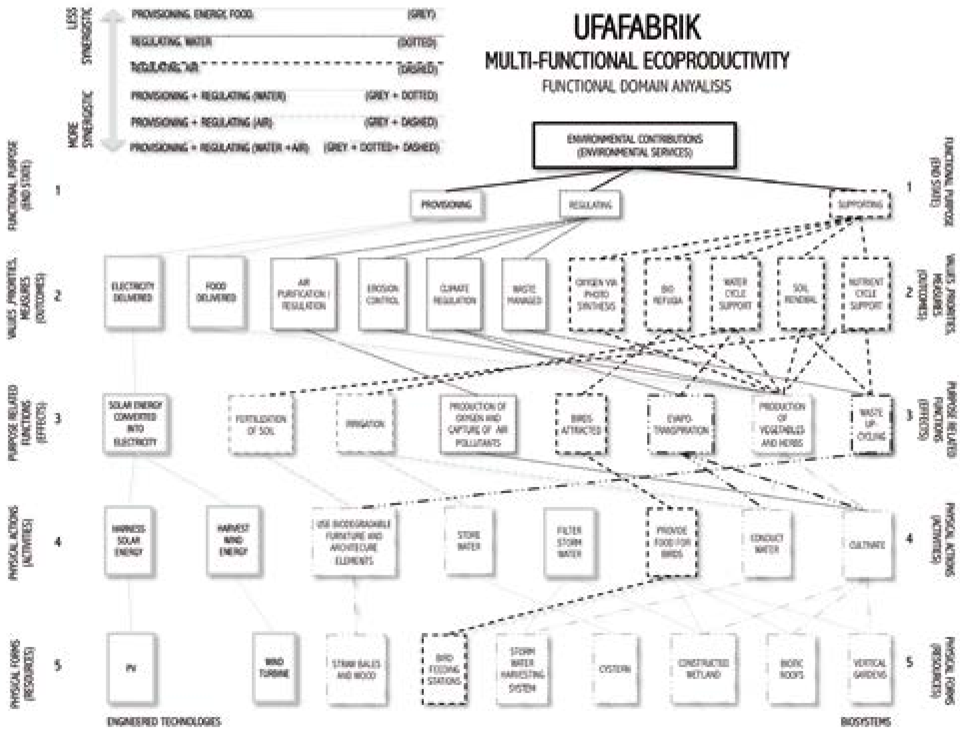


Figure 13. Abstraction decomposition space matrix for visualization of the overall UfaFabrik's ecoproductivity under a multifunctional approach. AIG

Figure 14. Opportunities and solutions to issues of urbanization through building and site ecoproductivity

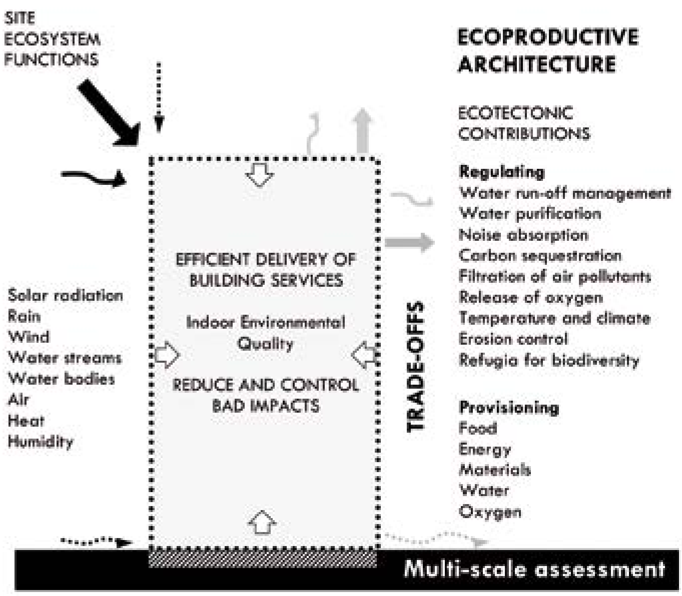


Figure 15. Urban trade-offs and co-benefits resulting from ecotectural contributions

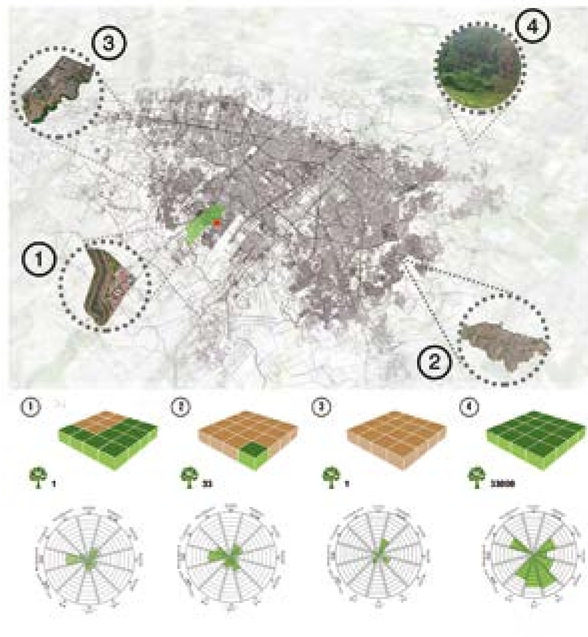


Figure 16. Ecoproductivity assessment baselines for the LAEBS method proposed applied to design projects in the city of Bogota. AIG, Ecoincremental Lab

lighting, shading device, rain cover, and sign pole. In addition to providing these services, Evapost was aimed to deliver a number of environmental contributions related to water management in urban settings: rainwater harvesting, evaporation, storage, and infiltration into the natural soil. The design team applied 4 functional principles found in vegetation: capillarity, albedo, edge effect and convection. Rainwater is cached by a warped surface in the upper part of the post. Water is stored in a micro-cistern located at the bottom, or infiltrated into the natural terrain. The post that supports the structure and conducts water by gravity or capillarity is simultaneously a multi-layered system that maximizes evaporation. This is achieved through an external 3D configured pored surface that changes color depending on the temperature and solar radiation received. The resulting outcome is evaporative cooling to combat the heat island effect in cities, a function mastered by plants.

12. CONCLUSIONS

Urbanization creates artificial settings that have little or no capacity to produce environmental services. Ultimately, this produces cities with critical environmental problems and overloaded natural ecoproductive systems.

Negative environmental impacts caused by building activity have extensively been studied and documented. It is widely accepted that buildings consume substantial amounts of energy, resources and materials. This concern has progressively influenced architectural practice over the last three decades via widespread design and construction principles aimed to reduce the ecological footprint and GHG emissions of buildings. However, the emerging positive development paradigm calls for human actions that not only are aimed to mitigate loads on the natural systems, but also can afford to enhance environmental quality via production of environmental contributions.

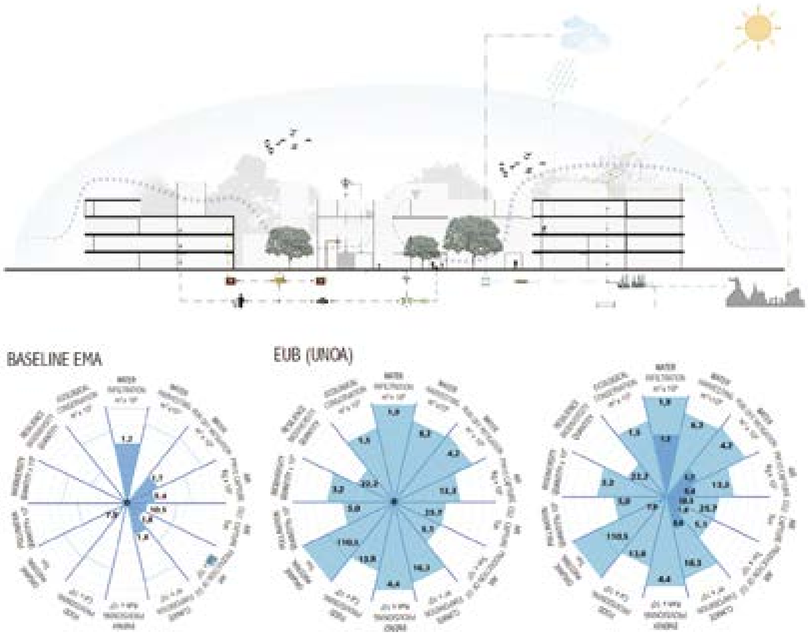


Figure 17. UNOA's EUB concept for urban master plan. Buildings and natural land are integrated via biotic components and engineered systems to create a number of environmental services related to water, air, energy, food, climate and materials

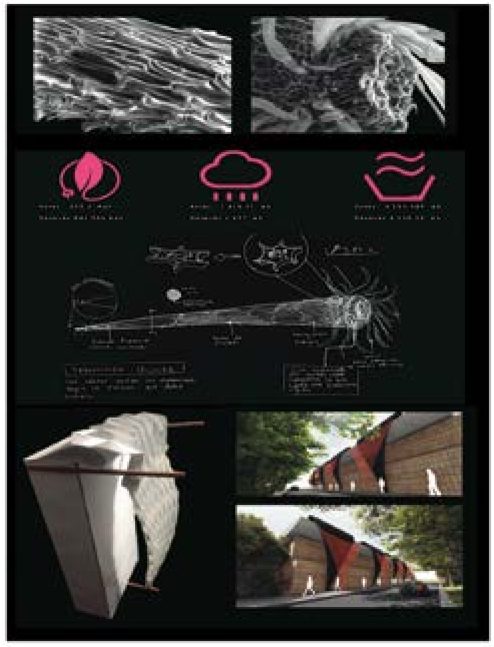


Figure 18. Biomimicry applied to ecoproductive architecture. Cactar Façade System, Daniela Vargas and Valentina García, Ecoincremental Lab

When this eco-positive mindset is transferred to architecture, buildings are conceived as 3D ecoproductive devices that can afford to create, embody and interface ecotectural contributions with their urban surroundings.

The visualization matrixes and methods presented suggest that assessment frameworks should follow an integrative approach, rather than using a method based on one single environmental aspect such energy generation or reduction of GHG. The functional domain analysis applied to the study case evidenced that incorporation of nature on sites and building results in greatest synergies and space-efficiency in the creation of ecotectural contributions, in comparison to the engineered strategies studied. However, further research and case studies are needed to expand the list of ecoproductive technologies applicable in architecture, and determine their substantive sustainability by combining the ecoproductivity assessment methods presented here with lifecycle analysis.

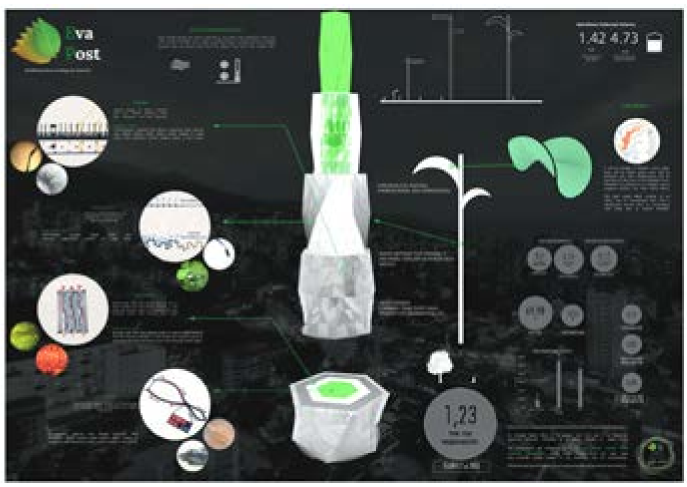


Figure 19. Biomimicry applied to ecoproductive infrastructure. Evapost, Ana Maria Soto and David Castillo, Ecoincremental Lab

Ecoproductivity is not an aspiration, but an attribute of objects, natural elements, sites or man-made designs. Through this attribute, it is possible to contribute to the restoration of the capacity of cities to maintain healthy environments, and involve building owner and practitioners of architecture in the creation of ecoincremental cities via trade-offs for win-win urban planning schemes and co-benefits. To achieve this aim, two shifts are crucial: using new lexicon that redefines the architectural practice, and developing novel assessment frameworks that evaluate buildings under multifunctional and multi-scale perspectives.

Through further advance of assessment frameworks, biomimicry and technology studies; ecoproductivity is likely to become an intrinsic attribute of architecture and the roadmap to ecoincremental cities in the coming years.

AKNOWLEDGEMENTS

I would like to express my gratitude to Werner Wiartalla, Dr. Manfred Köhler, Marco Schmidt and their team, for providing access to valuable technical data on UfaFabrik, and for guiding my field investigation. Thanks to Susanne Herfort and Dr. Stefan Köhler for supporting my research and tests on CO2 concentration and green roofs at the Institute of Agricultural and Urban Ecological Projects affiliated to Berlin Humboldt University (IASP), made possible by the German Ministry of Education and Research (BMBF), Stephen Lau and Christopher Webster from the Faculty of Architecture, The University of Hong Kong. I'm also grateful to the enthusiastic students of the Ecoincremental Research Lab at Pontificia Universidad Javeriana, and the members of UNOA team at National University of Colombia, who have developed fantastic projects following the ecoproductivity approach presented here.

REFERENCES

Bastian, O., et al. (2011). "Ecosystem properties, potentials and services - The EPPS conceptual framework and an urban application example." Ecological Indicators.

Breuste, J., et al. (2013). Urban Landscapes and Ecosystem Services. Ecosystem Services in Agricultural and Urban Lanscapes. S. Wratten, H. Sandhu, R. Cullen and R. Costanza. Chichester, West Sussex, UK, John Wiley & Sons, Ltd.

Cole, R. J. (2012). "Regenerative design and development: current theory and practice." Building Research & Information 40(1): 1-6.

Cole, R. J., et al. (2013). "Regenerative design, socio-ecological systems and co-evolution." Building Research & Information 41(2): 237-247.

Farber, S. C., et al. (2002). "Economic and ecological concepts for valuing ecosystem services." Ecological Economics 41(3): 375-392.

Farmer, G. and S. Guy (2010). "Making morality: sustainable architecture and the pragmatic imagination." Building Research & Information 38(4): 368-378.

Fisher, B. and R. Kerryturner (2008). "Ecosystem services: Classification for valuation." Biological Conservation 141(5): 1167-1169.

Gomez-Baggethun, E., et al. (2010). "The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes." Ecological Economics 69(6): 1209-1218.

Grant, G. (2012). Ecosystem services come to town : greening cities by working with nature. Chichester, West Sussex, Chichester, West Sussex : Wiley-Blackwell.

Guy, S. and S. A. More (2005). The paradoxes of sustainable architecture. Sustainable architectures. Cultures and Natures in Europe and North America. S. Guy and S. A. Moore.

New York, Spon Press. Taylor & Francis Group: 1 -12.

Ibañez, R. A. (2014). Biotectonics and positive ecoincremental change: Embracing the new eco-urban. In: Green Cities in the Word. Madrid, Editorial Agrícola Española S.A.

Lovelock, J. E. (2009). The vanishing face of Gaia : a final warning. London :, Allen Lane.

Lyle, J. T. (1994). Regenerative Design for Sustainable Development. New York, John Wiley & sons, INC.

Meng, L. and Y. Run-ming (2009). "Environmental sustainability modeling with exergy methodology for building life cycle." Journal of central south university technology. Springer 16(1): 118-123.

Olgyay, V. and J. Herdt (2004). "The application of ecosystems services criteria for green building assessment." Solar Energy 77(4): 389-398.

Pedersen Zari, M. (2012). "Ecosystem services analysis for the design of regenerative built environments." Building research and information 40(1): 54-64.

Reed, B. (2009). The integrative design guide to green building: Redifining the practice of sustainability. Hoboken, N.J., Wiley.

Sandhu, H. and S. Wratten (2013). Ecosystem Services in Farmland and Cities. Ecosystem Services in Agricultural and Urban Lanscapes. S. Wratten, H. Sandhu, R. Cullen and R. Costanza. Chichester, West Sussex, UK, John Wiley & Sons, Ltd.

Sarkar, C et all (2014). Healthy Cities: Public Health Through Urban Planning. Edward Elgar Publishers.

Schmidt, M (2009). Global Climate Change: The Wrong Parameter. RIO 9 - World Climate & Energy Event. Rio de Janeiro, Brazil.

Schmidt, M, (2005). Green roof and rain water harvesting strategies. Urban Sustainability Forum, Seattle, USA, 2005.

Schmidt, M, (2001). Rainwater harvesting in germany: new concepts for the substitution of drinking water, flood control and improving the quality of the surface watersreen roof and rain water harvesting strategies. Proceedings, 3º Simpósio Brasileiro de Captação e Manejo de Água de Chuva, Campina Grande - PB, Brazil, 2001.

Vitruvius, P. (2003). Vitruvius : ten books on architecture : the Corsini incunabulum. Roma.

Wackernagel, M. (1996). Our ecological footprint : reducing human impact on the earth. W. Rees. Gabriola Island, B.C. :, New Society Publishers: xi, 160 p.

Wallace, K. (2007). "Classification of ecosystem services: Problems and solutions." Biological Conservation 139(3-4): 235-246.

Wegner, G. and U. Pascual (2011). "Cost-benefit analysis in the context of ecosystem services for human well-being: A multidisciplinary critique." Global Environmental Change 21(2): 492-504.

WRI (2005). Ecosystems and Human Well-Being. Washington DC, USA.

WWF, et al. (2010). Living Planet Report 2010. Biodiversity, Biocapacity and Development. UK

CHAPTER 12
GREEN FAÇADES FOR SUSTAINABLE BUILDING

Carl Stahl
ARC GmbH

Green Façades combine aesthetics with ecological benefits: They bring green into cities and create natural living spaces. As part of sustainable building concepts, they reduce the negative ecological impact and help to protect the climate and environment. With I-SYS, X-TEND and GREENCABLE, CARL STAHL ARCHITECTURE offers a diverse repertoire of varying trellis systems made of stainless steel wire ropes and cable mesh. They facilitate individual design options and already decorate façades while the green is still growing.

The growing awareness of environmental and climate protection is increasingly being expressed in sustainable architectural concepts which unite ecological/economic elements with aesthetic design. In this context, green façades have a dual purpose: They are visually attractive with lush coverage, magnificent blossoms and changing colors over the seasons, and also store warmth in winter and ensure cooling in the summer. They provide natural sound protection and protect the façade from the damaging effects of dirt and weather.

MUSEUM STORAGE CENTER WITH INNOVATIVE CLIMATE CONCEPT

Over around 2,000 square meters, the Kolleksjesintrum Fryslân in Leeuwarden houses the collections of five museums of the Dutch province of Friesland in one central spot. The sparse building has an innovative, sustainable climate concept. On the one hand, it creates the ideal climatic conditions for storing the Friesian cultural treasures and at the same time optimizes the ecological and economical building footprint. Surrounded by a newly shaped natural landscape with domestic plant types, a green shell will grow around the museum storage center over the coming years. The I-SYS stainless steel wire rope system by CARL STAHL ARCHITECTURE serves as trellis structure for climbing vines along the vertical ribs of the rust red façade made of powder-coated aluminum. Over a total of 1,000 square meters, the four-millimeter-thick stainless steel wire ropes guide the plants along the right path. With the approximately 2,000 cross clamps used, green areas are created which integrate the storage center into the surrounding nature in an organic way.

Project:Kolleksjesintrum Fryslân, Leeuwarden, Netherlands

Architecture: LEVS Architecten, Amsterdam, Netherlands

Façade cladding: CARL STAHL ARCHITECTURE, Suessen, Germany

GREEN TRELLISES FOR RENOWNED MUSIC SCHOOL

From old music to jazz, from the development of music and dance to specialized post-graduate courses, the Conservatoire Niedermeyer in Issy-les-Moulineaux to the west of Paris offers students in-depth training in around 40 artistic disciplines. Lehoux-Phily-Samaha Architectes developed a modern extension for the renowned music school. It adds to the existing building to fulfill the contemporary needs of

around 1,400 students and employees. The new building is gradually being covered in green to ensure that it fits into its environment naturally and is an attractive upgrade for the public domain. GREENCABLE greenery systems by CARL STAHL ARCHITECTURE positioned vertically along the façade offer the climbing plants the perfect support. The four-millimeter-thick stainless steel wire ropes are simply secured in the cylindrical wall mounts with four through-holes and tightened by hand. The homogeneous anodic coating of the aluminum parts ensures longevity and a stylish appearance as early as the climbing plants' growing phase.

Project: Conservatoire Niedermeyer (extension), Paris, France

Architecture: LEHOUX-PHILY-SAMAHA Architectes, Paris, France

Façade cladding: CARL STAHL ARCHITECTURE, Suessen, Germany

VERTICAL GARDEN IN THE CITY

Tax consultants Frers-Sextroh & Partner have moved into a new office building on Bahnhofstraße in Westerstede which, with its modern architecture in gray steel and a large glass frontage, deliberately contrasts with the historic station building across from it. Its cubature sensitively integrates into the environment by incorporating the existing street lines on the eastern side. The I-SYS stainless steel wire rope system by CARL STAHL ARCHITECTURE was assembled to form diamond shapes in front of the offices and embrace the entire building with its surrounding escape balconies. The filigree stainless steel wire ropes with a diameter of six millimeters form an expansive net with a mesh width of 500 millimeters. It underscores the lightness of the building and acts as a trellis structure along the façade for plants. This is how, step by step, a vertical garden is being created in the town center, adhering to the sustainable building concept

with its low energy consumption, CO_2-neutral construction and air conditioning with geothermal energy.

Façade cladding with I-SYS, X-TEND and GREENCABLE by CARL STAHL ARCHITECTURE is an expression of responsible dealings with nature. With a simple design, easy to plan and straightforward to assemble, the greenery systems made of stainless steel cables and cable mesh are perfect for different types of façades and plants. As optimal trellis structures, they enable expanses of green in all sizes. A modular system of individual parts coordinated with one another forms the basis of flexible design opportunities and creative ideas. As they are weatherproof, durable and low-maintenance, they will provide decades of support for the living shell.

Project:FSP office building, Westerstede, Germany

Architecture: fischerarchitekten, Aachen, Germany

Façade cladding: CARL STAHL ARCHITECTURE, Suessen, Germany

GREENER LIVING WITH A VIEW

It is the first high-rise building in Switzerland to feature plants in its façade: the Garden-Tower in Wabern near Bern. The building is sixteen stories high and completely encased in delicate stainless steel mesh through which green shoots will soon be curling. But X-TEND by Carl Stahl Architecture is much more than a trellis structure for climbing plants. The mesh acts as fall protection as well as showcasing the building as a whole.

Wabern is one of the most desirable places to live in greater Bern, embedded as it is between the Gurten, the hill overlooking the Swiss capital, and the river Aare. Now a new kind of tower rises up in the foreground of the panoramic view of the Gurten, its amorphous contours catching the eye for miles. The concept of the Bächtelenpark residential area is heterogeneous: The tower at its center is 53 meters high and accommodates 45 apartments each with three-and-a-half or four rooms. "Living with a view" is what Basel-based architects Buchner Bründler have embodied in exceptional high-rise architecture.

INTEGRATED IN LANDSCAPE AND NATURE

The basis of the Garden-Tower is a polygon which repeats itself over the entire height of the building. The concrete slabs jut out on every side, offset from one floor to the next, bending up and down on the horizontal plane. They look like a drawing of mountain topography and thus underscore their relationship with the landscape. The apartments with their varying floor plans face two if not three directions. Balconies with at least 45 square meters of space, some deep, some more elongated, and always in the opposite direction to the expansive areas inside, extend the living area. At the same time, the surrounding concrete slabs are a kind of substitute garden with a unique view of the surrounding nature.

CLIMBING GARDEN

Instead of protective balustrades, the building is fully encased in a mesh of stainless steel cables by Carl Stahl Architecture. X-TEND provides a delicate trellis structure which can be planted with climbing plants. A natural green façade will gradually grow over the Garden-Tower providing shade as well as being a striking architectural feature. Positive side effect: The green curtain absorbs CO2, generates pure air and thus plays an active role in climate protection. This makes the residential tower unique indeed. It is the first high-rise building in Switzerland to have a green façade. To ensure it always appears lush green and at the same time fulfils the fire protection regulations, the architects integrated an irrigation facility in the greenery system with X-TEND which automatically detects whether the plants need watering. A total of 100 plant tubs were installed on the floors: These will give rise to a full cover of green on up to 1,200 square meters of façade space. The architects also paid particular attention to which plants were chosen. They all correspond to the different light conditions on the four sides of the building. This guarantees even coverage. Gaps in the balcony areas break up the green façade, bring light into the apartments and frame the view of the landscape for those inside looking out. The architects commissioned stainless steel mesh experts from Carl Stahl Architecture from Suessen in southern Germany with the planning of statics, execution and assembly, as well as the actual assembly itself.

X-TEND AS FALL PROTECTION

In addition to its function as a design feature, the X-TEND façade acts as fall protection without the necessity for any further barriers which would negatively impact the organic appearance of the Garden-Tower. Because the preassembled cable mesh construction retains its form regardless of its dead weight and any loads. The opposing curvature and tension of the cables generate stability. To keep mesh vibrations as minimal as possible when leant against, the experts from Suessen ensured the façade mesh of the green residential tower was under high tension – a purely psychological measure to make residents feel safe even at lofty heights.

DIVERSE, DURABLE AND SAFE

X-TEND from Carl Stahl Architecture opens up virtually unlimited design opportunities in lightweight construction architecture. The stainless steel mesh by Carl Stahl Architecture enhances the static advantages of the cable spatially. The intelligent combination of stainless steel cables and ferrules is the key to a range of shapes for engineered cable mesh constructions. X-TEND is both a safety and design element at the same time - its uses thus accordingly diverse, both inside and outside buildings. Alongside fall protection, balustrade in-fill, façade cladding and trellis structures for green wall systems, X-TEND is a carrier structure for all kinds of decorative or functional components: from sequins, stripes and letters made of all kinds of materials through to LED dots and photovoltaic panels. The opposing curvature of the cables permits light, transparent structures possessing extremely high load capacity. High-grade stainless steel guarantees durability. The European Technical Approval (ETA) for X-TEND as vertical and horizontal fall protection facilitates the planning for both new and existing buildings. X-TEND Colours adds a touch of color in blue, green, red, gold, white or black. Thanks to the fine emission-free polymer coating, the cable structure remains visible. The colored stainless steel mesh provides additional flexibility for creative uses in architecture and interior design.

Project: Garden-Tower, Wabern (Bern), Switzerland

Architecture: Buchner Bründler Architekten, Basel, Switzerland

Mesh façade: Carl Stahl Architecture, Suessen, Germany

ABOUT CARL STAHL ARCHITECTURE

Balustrade in-fills and fall protection, green façades, spectacular LED light installations and complex zoo enclosures: With the experience of more than 25 years, CARL STAHL ARCHITECTURE creates impressive architectural projects with stainless steel wire ropes and mesh. The services CARL

STAHL ARCHITECTURE offers worldwide as a complete package for architectural projects range from consulting, planning and structural analysis to manufacture and assembly. As an ISO-certified company, we fulfill the highest quality demands on a daily basis. CARL STAHL ARCHITECTURE prides itself on its climate-neutral operations. Sustainability governs our policies and actions. We ensure the value chain with our own production facilities in Europe as a German family company that has been active since 1880.

Green wall.
Santalaia bulding.
Colombia.
Paisajismo urbano

PART 2
COUNTRY EXPERIENCES

Ufa Fabrik. Berlín.
I. de Felipe

CHAPTER 13

EXPERIENCES WITH ECO ARCHITECTURE IN BERLIN LESSONS LEARNED FROM THE 1980s FOR TODAY'S SOLUTIONS

Manfred Köhler*
koehler@hs-nb.de

Ulrike Grau
ugrau@yahoo.de

SUMMARY

In the 1980s in Berlin (West) the International Building Exhibition inspired several urban planner groups to realize visionary urban concepts. Green roofs and green facades were symbols, but also other technology, so called eco bricks were used, and energy consumption, waste management, mobility and forms of new housings were improved.

This chapter focuses on four of the key projects and tries to evaluate these pioneers in Green architecture, answering the following questions: Are these concepts still up-to-date today? Are the citizens involved in these projects still happy with those experiments? What did we learn from these projects for today's architecture?

The study shows that these projects are still exciting today and that they still work well. Some of the technologies used today have a more professional style and are updated for the future with smart solutions and integrated into building certification. Knowledge of the performance of the green elements in detail is still fundamental today and the functionality of biodiversity is still the important basis.

1. INTRODUCTION

Eco-Architecture includes a wide range of technologies around greenery, low impact design, energy savings, a different traffic concept as well as circle economy. Today there are a number of environmental indicators available that help to evaluate the quality of green buildings, such as BFF [1-1]*, GDF [1-2] and label systems from C2C [1-3] to Green building certification. The last one includes values, which allow a calculation of cost reduction by using green technologies [1].

The green building movement is present around the globe now. As key thinkers for this movement, the following architects gave important impulses, such as: Ken Yeang (Malaysia) [1-4], Emilio Ambasz (Argentina) [1-5], James Todd (USA) [1-6], or Garry Baverstock (Australia) [1-7].

Focusing on Berlin in Germany, a number of architects have to be mentioned, such as: Engelbert Kremser [1-8] or Martin Küenzlen [1-9]. The massive success in Berlin (West) from the 1970s was only possible because of the specific economic situation there. The economic post war activities were concentrated in other regions of Germany. At that time there was a massive need to renovate the remaining buildings after the war. At the time it was a burden for house-owners to have rental buildings – the income was not enough to maintain the buildings. Grass root initiatives began to think of cities in a new format with a greater amount of self-help.

This spirit was caught up by people who understood how to use the formal instruments of urban planning such as IBA (International Building Exhibition) or BUGA (Federal Garden Exhibition) and the academic activities around the new topic of urban ecology, driven by persons, such as Herbert Sukopp and Reinhard Bornkamm [2], fathers of the academic urban ecology.

Eco Architecture is a type of sustainable architecture which includes technical, social and economic procedures with the aim to reduce the negative impact of buildings to nature.

Berlin as a living lab of post war Architecture

The Berlin situation after World War II was unique in the world. The rapid development after the beginning of the industrial revolution in Europe at the start of the 20th century was completely disrupted by two World Wars and their political results.

After World War II there was a situation of economic vacuum with uncertain conditions for investors. Indicator for this were the extremely low prices for houses in Berlin (West). But on the other hand, the concentration of academic knowledge, the lost places and some political "no man's land" like the big railway and industrial brownfields "Brachen" [1-10] were spaces for creativity. Ecologists were able to study "potential nature on artificial grounds" for a period of some decades.

Some remaining places of unique architecture with roots from the "Bauhaus" exist as Reform architecture such as "Weiße Stadt", Reinickendorf, (Arch. Martin Wagner [1-11]) or "Hufeisensiedlung" Britz, (Arch. Bruno Taut [1-12]). All these concepts combined social housing with integration into the landscape. What these concepts have in common is that they are children of their time and one can still understand the spirit of that time today – they have qualities that make them pleasant even for today.

Experimental buildings and the need to build a large number of housings, that was the demand of the first International Building Exhibition Berlin (IBA) in 1957 [1-13]. After World War II, the focus was on the Bauhaus concepts and realized multi-story houses in a

**online sources are marked like this [1-1], print media [1]* park environment of the Tiergarten, among others by architects such as Alvar Aalto [1-14], Le Cobusier [1-15] or Oscar Niemeyer [1-16]. They are still important as buildings today, but they were far away from the housing style of the majority of people living at that time.

At that time, open spaces were reduced to urban parks as visible but not functional green spaces. The city was transformed into a car-dominated city like almost everywhere else in the world. The major axes of the former German capital have contributed to this transformation. The Ernst Reuter Platz is a great example for this.

Normal rental buildings still had poor post World War conditions, with low-insulated windows and emitting oven heating systems. The following years, Berlin became an inspiring experimental "real lab", since the economy was quite down. The major business development in Germany took place in other regions.

Thus, the idea of the IBA was again developed, (IBA 1977-1987) [1-17]. One of the highlights was an international symposium with speakers such as Hundertwasser on the 30th of October 1980 [1-18]. This city was a real laboratory for ecological urban planning ideas and their improvement in the experimental stage. 12 goals were defined, with social, financial and ecological implementation. These theses changed the architectural philosophy from a technical to a sustainable goal – from then until today it is still an ongoing process.

About 30 years after this beginning, it is time to take stock of whether this idea is a success and what the next steps are on the way to reducing the environmental impact of architecture. The IBA activities were accompanied by grass root activities of "squatters" since the 1980s building occupation. The idea of renovating houses apartment by apartment dominated, rather than destroying the entire block and rebuilding it later. The protection of the social interaction between the existing tenants was a key aspect of such type of renovation. Greening buildings was one key element, at that time also in an informal early stage.

One of these related working groups was the "Stiftung Naturschutz Berlin", 1982 [3] which developed new spaces for apartments in the attic of the buildings. In a 4-story building, the use of the roof apartments means about 20% more living space on the same ground surface. This solution was combined with green roofs as an insulation value for normally less insulated roofs.

The cultural center ufa-Fabrik Berlin is highlighted here as one of the squatting projects in combination with ecological, socio-cultural new activities with a reasonable number of eco features.

2. GREEN BUILDINGS AT THE BEGINNING

A selected number of Berlin's key eco-projects will be described and interpreted here in order to answer the questions about the insights gained and lessons learned.

2.1 Eco houses, Berlin, Rauchstrasse, Corneliusstrasse

This IBA project idea was developed by the architect Frei Otto from Stuttgart [1-19]. On pre-produced concrete levels, individual maisonette houses should be constructed by the individual owners. It was a yearlong decision procedure to select from a group of about 1000 interested families, finally 26 private groups were allowed to design together with architects eco-friendly homes [1-20]. The first passionate idea of a 60-meter-high tree house was too ambitious at that time (see Fig. 1a). At that time the 22 m high eaves were a fixed paradigm in Berlin. This type of house was about 30 years too early.

The urban planning background idea of this project was to build space-saving private homes with a reduction of the paved areas


Fig. 1a: "Baumhaus Frei Otto" the concept for the Ecohouse Rauchstr., 1976 [1-21], 1b: Google earth picture, Dec. 2018


Fig. 2a, 2b: Eco houses, Frei Otto and others, Rauchstr. Berlin (left); Engelbert Kremser, organically formed buildings, here: Pflanzenschutzamt, Berlin from 1990 (right)

in order to protect farmland space in the surrounding area of cities.

Today, this complex is a private area without public access, but there are presentations online available on YouTube to hear some owners explain why they are proud to be a part of this project in Berlin.

2.2 Block 108, Berlin-Kreuzberg – Paul-Lincke Ufer

This was the first complex urban eco study [4, 5] to investigate the abiotic and biotic function of an inner-city building block. This case study quantifies economic and ecologic facts such as traffic, waste, green components. After the implementation in 1985, the vegetative components were monitored for several year. [5 Köhler and Schmidt]. The vegetation development of the roofs is still monitored [6, 7]. In fig. 3a, 3b a map of this block and a first calculation about the waste production at the beginning is shown.

The study [4] counted 1220 citizens living in this block on a surface area of 39,000m², with an actual vegetation of 4,000m². In the planning scenarios were included:

- Potentially 25,000m² green facade and nearly 20,000m² of green roofs is possible (almost all buildings could be greened). In the longer term, 65,000m² should be greened.

- 20% self-supply with urban garden products was planned, as part of the green roof strategy, roof top farming as a concept.

- Recycling economy within the block.

- Rain water, sewer water systems.

- Thermal insulation of all buildings.

- Participation of all citizens of the block in the planning process.

Finally, part of the concept was implemented with funds from the Federal Agency for Nature Conservation (Bundesamt für Naturschutz), the Berlin Senate Department for Urban Development and Housing, retrofit 1984-1986, and a later monitoring phase, which again was funded by the Bundesamt für Naturschutz, 1986-1996 [6].

The focus was on the extensive green roofs and facade greening. For these a temporary balcony system was used, "System Minke", which consisted of PVC bags which were attached to the outside walls and were planted with fast growing climbers. These developed well in the first few years. But at the latest after 10 years the Boston Ivy (*Parthenocissus tricuspidata*) covered the complete backyard facades. The temporary planter boxes are still hanging in 2018 and are in operation for individual plantings of e.g. tomatoes.

The 10 different green roofs investigated here have been monitored once a year since the beginning. These green roofs were given a final layer of a preproduced vegetation mat. The vegetation traits over the year are documented in Köhler, 2006 [7] and Ksiazek-Mikenas, et al., 2018 [8]. It is still today a *Festuca ovina* dominated grass roof with several *Sedum* species and a predominant cover with *Allium schoenoprasum*.

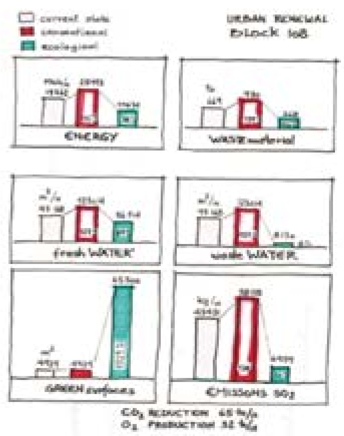


Fig. 3a, 3b: Block 108, case study about a holistic urban ecologic project, origin: Oekotop Berlin, Küenzlen et al. [1-22]

Fig. 4a: Project start 1994, (here with Friedrich Bartfelder and Michael Zimmermann, a first inspection tour on the roof.
4b: Summer 2018: green roof landscape today.
4c: Backyard 1994 at the beginning.
4d: 2018: Backyard Paul-Lincke Ufer 44. After about 5 years the Parthenocissus reached the full 22 meters height of the facades. The temporary planter boxes on the facade are overgrown.

So, was the Block project a success?

It was a pioneering structure. Several blocks followed in Berlin over the years, many of which were successfully retrofitted with the so called "Strategies for Kreuzberg" [9]. Green roofs and roof apartments became fashionable and after the reunification, Berlin-Kreuzberg became one of the central and cool districts of the German capital. Many of the eco-concepts, such as waste management, are now almost normally integrated into the city.

The participation procedure is common practice in urban planning today. In this block, in the end, the normal relationship between owners and tenants became reality and differs from the early ideas.

2.3 Ufa-Fabrik, Berlin-Tempelhof

From 1921 to 1970, a satellite of the UFA film studios was located on an 18,500m² site in Viktoriastreet on the southern edge of Berlin. Here important films of the 1920s were

Fig. 5a, 5b: One of the ufa-Fabrik Green roofs, here above the school project, with various PV installations. Right: a loam test facade with hay and loam, result of a workshop at ufa-Fabrik.

premiered in Berlin. After World War II, this area was disconnected from the main film studios in Babelsberg and was to be retrofitted with new housing projects.

In June 1979 squatters occupied this area and since then have developed it into a cultural, ecological and social center. In the following years it was legalized and integrated into the cultural locations of the city.

Eco features were integrated into the renovation process, such as:

- Green facades with climber plants,

- Green roofs, various types of construction, (monitored annually by M. Köhler since 1992),

- Rainwater concept; the integration was developed on the basis of the site's own water supply well,

- Alternative heating systems, block heat and power plant,

- Experiments with various photovoltaic (PV) systems, included since 1999, also in combination with green roofs,

- Alternative construction materials for buildings, loam brick earth-construction. (more on the ufa-Fabrik webpage) [1-23]

2.4 BUGA Houses

Almost at the same time, another project was launched in combination with the Federal Garden Exhibition Berlin (BUGA 1985). Interesting is the "earth architecture" by Engelbert Kremser. Freely shaped hills, covered with concrete or his design of an organically shaped administration building, the "Pflanzenschutzamt" (Fig. 1b).

As a contribution to the exhibition BUGA 1985 the following architects (Tab. 1) were invited to present their answer to the "State of the Art Eco architecture" for Berlin. The invited architects were: Thomas Herzog [1-24], Erich Schneider-Wessling [1-25], Otto Steidle [1-26], Peter Stürzebecher [1-27] and Bernd Faskel [1-28].

They should present their ideas for affordable space-saving single-family homes. Green technologies such as Green roofs, green facades, Winter-garden areas and urban farming concepts should be included – and as

Table 1: Architects and their main concepts of the BUGA houses (see also fig. 6)

Architect	Characterization	Main green features
1. Peter Stürzebecher 1941-2012	Compact single houses "Freistehende Einzel-häuser"	-Eco gardens -Green roofs -Hedges
2. Otto Steidle 1943-2004	Double-houses "Doppelhäuser"	-Energy concept -Earth architecture subsurface -Winter-garden as energetic buffer
3. Erich Schneider-Wessling 1931-2017	House in house "Haus im Haus-Objekt"	-Complex greening concept -Intensive roof gardens -Indoor greening and urban gardening features
4. Thomas Herzog *1941	Chain houses "Reihenhäuser"	-Urban roof garden -Roof terraces -Indoor urban gardening with direct ground contact
5. Bernd Faskel *1943	Back-to-back–houses "Back-to-Back-Häuser"	-Compact shape of the building structure, energetically optimized, four compact houses together, -Indoor greening as a climate buffer, -Climbers and espalier fruits.

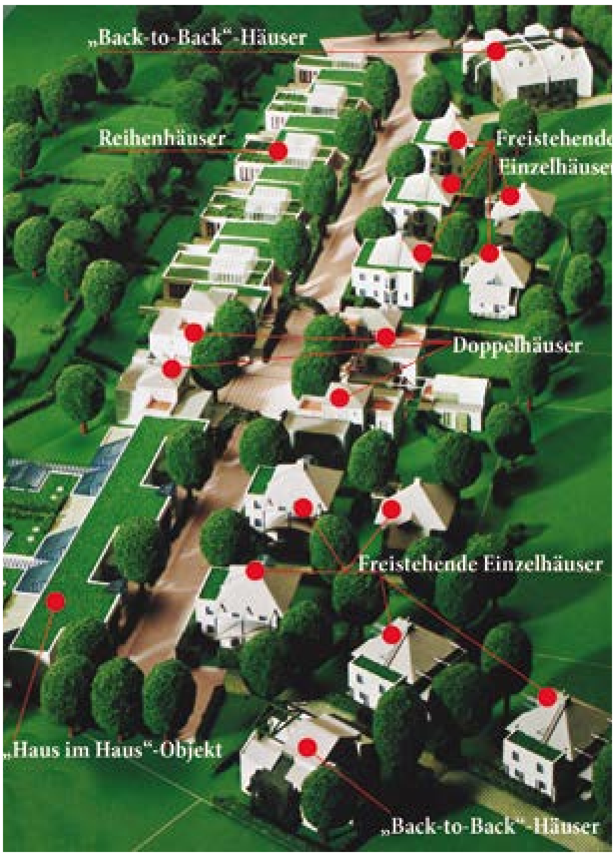


Fig. 6: Model of the neighborhood with the names of building groups and architects (after: DEGEWO, 1985, completed).

special addition some ideas of Bill Mollison [1-29] or Declan Kennedy [1-30] on permaculture – if possible.

This area was opened as part of the garden exhibition in 1985 – and then closed as private homes. In the following the concepts of the 3 most innovative ideas are presented. In 2012 a questionnaire was executed by Natascha Kuiveda for her Master thesis to find out more about the success of this project. Questions asked included: How satisfied are the owners with the eco projects? What is the evolvement of the eco technology since that time? How would such houses be designed today? [10].

The productivity parts with permaculture concepts were too much work in the long run and in most of these houses reduced to ornamental roof garden structures. These chain houses have a smart energy concept, larger parts of the roof are integrated as sub-surface of the rampart in direction to the BUGA park. Winter gardens serve as energy buffers and/or solar collectors (Fig. 7a and 7b).

Schneider-Wessling's house (Fig. 8a, 8b and 9) connects several levels with complex greening, intensive roof gardens and an atrium for larger plants.

Fig. 7a, 7b: Chain house roof gardens, from Thomas Herzog, left: picture from 1990, right: the same house 2018.

Fig. 8a, 8b: House in house concept, Erich Schneider-Wessling, street side, 9b: Garden side. In the background the double houses of Otto Steidle.

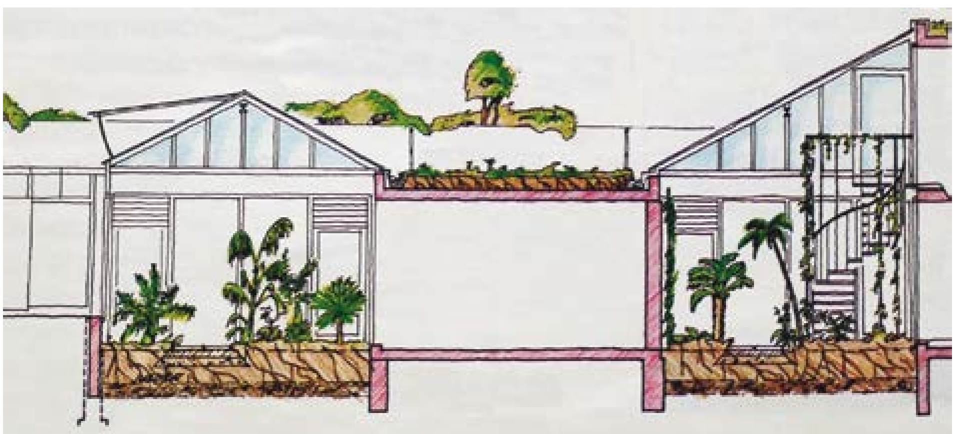


Fig. 9: Cross section of the “house in house“ from Erich Schneider-Wessling.

Fig. 10a: Chain house greenhouse level, Thomas Herzog, 2014 (left), 10b: Greenhouse of the back-to-back houses, Bernd Faskel (right).

Fig. 11a: Climber at the back-to-back houses of Bernd Faskel, 11b: Front of the chain houses.

Bernd Faskel's back-to-back houses follow the idea that common central walls reduce the energy demand of houses and reduce the required ground floor for each building, but also with a ground garden space of about 250m². Four homes become one complex, but with individual green features from roof terraces to winter gardens.

The idea of installing intensive production glasshouses connected to the normal ground has been preserved in only half of the buildings. The others transformed it into normal rooms. Reasons for this: no time for the gardening work or some difficulties with condensation water on the glasses. The remaining glasshouses of this type impress with their lush greenery. Most of them in Mediterranean style with olives, thyme and others. They offer an excellent quality of living.

In 2015 the residents were asked about their satisfaction with these houses [10]. Some results of the questionnaire are shown in the following figures 12 and 13.

An overall satisfactory result on the additional green features in the buildings. Half of the residents have been here since the beginning in 1985, the other half also lives here for a long time. There are very few changes in the houses.

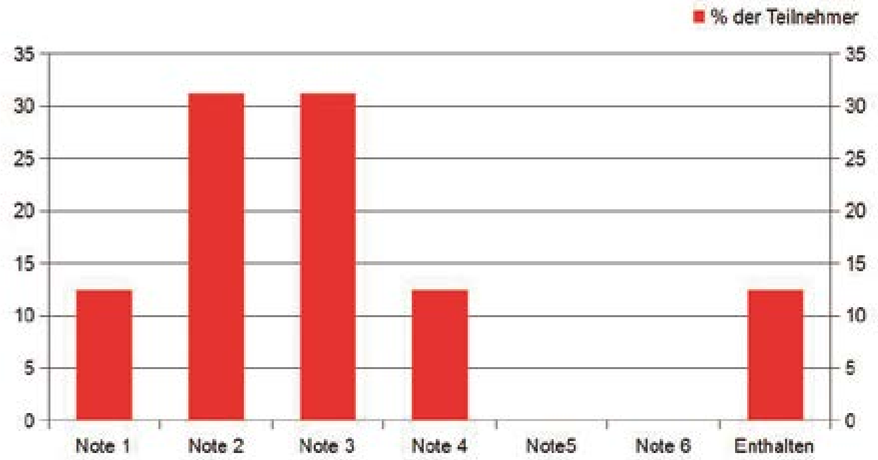


Fig. 12: How do you evaluate the opportunity of obtaining vegetables and herbs for yourself on your building? Assessed in school grades and presented in percentages of participants (Teilnehmer). Assessment: Note 1 = very good, 2 = good, 3 = satisfactory, 4 = sufficient, 5 = inadequate, 6 = insufficient; Enthalten = abstained.

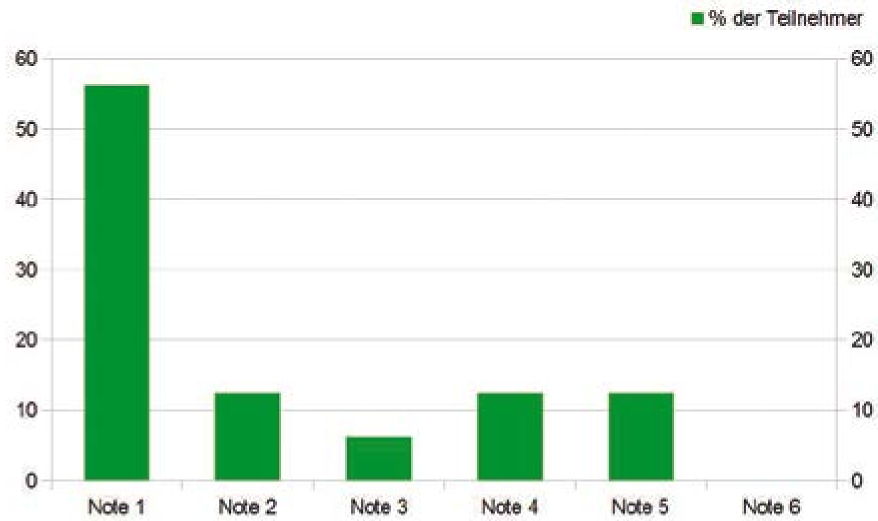


Fig. 13: How do you evaluate your extra space on the roof, atrium or winter garden?, assessed in school grades and presented in percentages of participants (Teilnehmer). Assessment: Note 1 = very good, 2 = good, 3 = satisfactory, 4 = sufficient, 5 = inadequate, 6 = insufficient.

In contrast to other eco housing projects, this area was not sold in a community-based selection process. The citizens are satisfied with the project, but no additional focus has been placed on social relations.

In 2016 another in depth evaluation was carried out at the BUGA houses "Am Irissee" [11]. If such buildings were erected today, what would be different? Finally, tab. 3 gives some answers. In general, most features would also be installed, but in recent years there has been a lot of progress, beginning with the types of insulating glass types, integrated shading and digital regulation in relation to weather conditions.

Tab. 2: Conclusions from the questionnaires (n=16 households answered)

Questions	Yes – % of the answers	No - % of the answers
Are you happy with the winter/roof gardens at your home?	100	0
Are the winter garden/green roofs places for relaxation?	94	6
Is the necessary maintenance of the winter/roof gardens a burden for you?	13	87
Do you feel a higher quality of life in comparison to a home without such green structures?	100	0
Do you think there is a better relationship between the neighbors compared to conventional housing projects?	38	62
Do you also use your glasshouse for growing food during the cold season?	50	50

Tab. 3: Evaluation of the Eco houses BUGA 1985 – in 2016 and a summary of the current green building technologies of the last years (2018).

	Aims	1985	Evaluation	2018
1	Compact neighborhood, called "space saving buildings"	X	Success	X
2	Urban food production	X	Too difficult, only marginally realized	X
3	Intensive Green roofs	X	Roof terraces are in use and a great benefit	X
	Green Facades	X	Success	X
	Passive heating/cooling	X	Success	X
	Future ideas of the last years.			
	Energy plus buildings			X
	Solar heating			X
	Individual PV – Energy systems			X
	Rain water systems			X
	Local biodiversity concepts			X
	Living walls			X ?
	Digital smart homes (traffic, energy, consumption,...)			X ?
	Urban food production			X

The intensive use of rainwater or sewer water had a great success in Germany after 2001 and is today a well-developed technology, here it was still at the very beginning.

The discussion about food production is also very diverse in Germany; on the one hand, it is fancy today, but not necessary due to the low vegetables prices on the markets. Such concepts would work if citizens preferred "their own", "fresh", "local" food.

3. LESSONS LEARNED AND CURRENT DEVELOPMENTS

3.1 Summarized typology of the described projects

These described "eco houses" still work today. Knowing that normal calculations in architecture, especially in the case of low-cost buildings mean a life expectancy of about 45 years, these houses are now in the age to be removed and to construct new houses.

The very few negative responses to these projects indicated though that the owners are overall still happy and do not like to move or change. This confirms the quality and gives an understanding of the fact that social components are important in addition to all technical features. These residents want to stay there as long as possible at their old age. This means that it is also a major aspect of architecture that the houses are adaptable and functionally changeable for different purposes in different life phases – an aim that the Bauhaus architects also had as a planning goal.

In the 1980s it was only a small group of enthusiastic people who really wanted these technologies.

Special times led to special solutions. In Berlin in the 1970s it was such a time. Only the combination of creativity (grass roots – cross thinkers), academia and people who can bring this pressure of the street to successful formal solutions.

Today we have many regulations – some things are formalized and now by law regular politics (Energy savings, greenery, low impact design, life cycle analysis), other things are too formal and hinder creative ideas.

The greening of buildings as one of these elements is today technically well developed, the benefits are described and usable for the typical architecture.

Tab. 4: Project data of the four case studies.

Criteria	Eco house Rauchstr.	Block 108	Ufa-Fabrik	BUGA 1985
Ownership	Building lease, "Erbbaurecht"	Several individual owners	Legalized	Individual owners
Size	25 apartments 100 + persons	200 + apartments 2200 + residents	30 + residents and 180 employees	26 family houses 100 + persons
Architects	Frei Otto, Bernward Derksen, Alessandro Vasella, Eckhard Hahn, and several others for the individual apartments' planning.	Martin Küenzlen and the team Oekotop	n.a.	Bernd Faskel, Thomas Herzog, Erich Schneider-Wessling, Otto Steidle, Peter Stürzebecher
Decision making process	Selection procedure, common aim discussion	Owners discussion and neighborhood convention	Squatter forum	Discussion forum
Year of establishment	1983-1992	1984-1986	Since 1979	1984-1986
Financing	Private, state, federal	Private, state, federal	Private, state, federal	Private, state
Overall owner	Private- building lease	Private	Building lease	Private
Satisfaction of the residents	High	High	High	High
Urban type	Compact villas	Block structure, 5 stories	Individual buildings in parkland	Compact chain houses, single houses
Age	New	Retrofit	Retrofit	New
Located in Berlin	Inner City	Inner City	City outskirts	City outskirts

Tab. 6: Eco features realized

Criteria eco-features	Rauchstr.	Block 108	Ufa-Fabrik	BUGA 1985
Green roofs				
Extensive	X	X	X	X
Intensive	X	X	X	X
Urban farming	-	-	X	X
Biodiversity roof	-	-	(X)	-
Green facades				
Climbers	X	X	X	X
Living walls	-	-	-	-
Energy concept	X	X	X BHKW*	X
Waste concept	X	X	X	n.a.
Mobility concept	X	X Bicycles	X	n.a.
Solar energy	X	-	X	n.a.
Rain water management	X	X	X	n.a.
Indoor greening	n.a.	-	-	X

** BHKW – Blockheizkraftwerk (combined heat and power unit)*

The associated "green infrastructure" technologies have developed massively in recent years. The first projects can be described as "children of their time", but all these projects are unique, and lessons have been learned: if you build with high quality environmental features of the time, it will remain an important contemporary document and be loved by the house owner.

A particular plus is when architects have been able to design it flexibly, i.e. to be upgradeable and modifiable, when other technologies are available in the future.

Green features are only associated with low additional costs, but highly recommended with good quality for the next generation. The investment in green features pays for itself over the period of use, as documented by a reasonable number of publications.

3.2 Conclusion / Outlook for the next generation of Eco houses

Much can be learned from all these four projects. Table 7 concludes some basics with a difference between small and big projects. A second aspect can be looked upon inside cities with very limited space or in the suburbs with more open ground around the buildings, which facilitates the implementation of many features, e.g. the required water tanks or retention/filter beds.

Furthermore, it is important from the beginning to define the key points of projects, e.g.

- How much participation work is expected from the residents?
- What are the traffic needs of private or shared cars?
- Acceptance of rainwater and sewer water use.
- Difference between private and shared spaces.

Summarized, it can be said that such eco-houses are of a great benefit for citizens and the environment [1]. The contribution of indoor greenery to improve indoor air quality has long been underestimated [12]. These technologies can be used for both new and retrofit installations [13]. Green roofs are a now a well-established technology for reducing heating and cooling requirements around the globe [14]. Today there is a large number of certification and evaluation systems in place to obtain certified eco buildings [15]. But in addition to such certification, creative

Tab. 7: Recommendations and possibilities for future projects, inner city/city outskirts; small projects for about 100 citizens, large ones for 2000+ citizens

Eco criteria	Small projects	Large projects
Green roofs		
Extensive	X	X
Intensive	X	X
Urban farming	-	X
Biodiversity roof	-	(X)
Green facades		
Climbers	X	X
Living walls	(X)	(X)
Indoor greening	X-	X-
Garden green	Where ever possible	Where ever possible
Energy concept	X	X BHKW (Block heating system)
Waste concept	X	X
Mobility concept	X	X
Solar energy	X	X
Rain water management	X	X
Overall monitoring/evaluation		X

architects are important, with a broad understanding of local opportunities and the specific needs of the clients – to find the best solution for the unique location of each project. Evaluation helps, but it cannot be the only criteria [16]. Green certification today connects economy, ecology and the life cycle benefits of buildings [17].

We learned from Chan et al. [18] that greenery is an important factor to make dense cities tolerable, to hide massive buildings behind vegetation or to create vegetated spaces to lose sight of neighbors. Such new factors help to compare eco projects according to a number of criteria [19] in order to find the best solution for a property. For researchers, the message is included, despite the large number of studies published in recent years [20], there are still many opportunities to go into more detail in terms of material, function and cost–benefit analysis. The related biodiversity is such a field for more detailed surveys in all climates and types of eco-projects [21]. The same applies to biotechnological solutions, the quantification of energy savings related to the incorporation of vegetation on roofs and on facades [22].

Today, about 40 years after the described pioneers started their enthusiastic projects – about a professional lifetime later - such projects are no longer unique, but they still need some years to become the standard construction method. Germany's so called "Weißbuch" procedure lead into this direction [23]. Today it is not a question of finding more solutions, but in detail a lot of future innovations can also help for future developments.

Public competitions and increasing awareness, as planned for 2019 in Berlin, can now transfer these eco ideas to the broad public in Berlin [1-31]. Some ideas take 40 years or more, but they are still alive. Like the idea of the building-integrated agriculture. Details have changed and are adapted to new conditions with more digitalization included, but the basics are still the same.

REFERENCES [IN BRACKETS FROM 1 TO 23]

[1] Zhang, L.; Wu, J.; Liu, H.; 2018: Turning green into gold: A review on the economics of green

buildings. Journal of Cleaner Production 172: 2234-2245.

[2] Sukopp, H. & R. Wittig, 1998 Stadtökologie. G. Fischer. Stuttgart.

[3] Bartfelder, F. Köhler, M. 1982: Fassadenbegrünung und Stadtklima. In: Stiftung Naturschutz Berlin (Hrsg.). Das Gründach. Berlin. 5-36.

[4] Autorenkollektiv (ed.) 1981: Systemstudie zur ökologischen Stadterneuerung für einen innerstädtischen Gebäudekomplex. UFOPLAN, Bundesmin. des Innern. Bericht 103 01 109 – i.A. UBA, IBA. 366 S. online available: https://fhxb-museum.de/xmap/media/S7/T1791/U26/text/fhxb_spk_gutber_00036a_72.pdf

[5] Küenzlen, M. and Autorenkollektiv. 1984: Ökologische Stadterneuerung. C.F. Müller.

[6] Köhler, M. and M. Schmidt, 1997: Hof-, Fassaden- und Dachbegrünung. Zwölfjährige Erfahrungen mit einer Begrünungsutopie. Landschaftsenwicklung und Umweltforschung. Nr. 105. TU Berlin. Schr.R. Landschaftsentwicklung u. Umweltforschung. 1-177.

[7] Köhler, M. 2006: Long Term Vegetation Research on two Extensive Green Roofs in Berlin. Urban habitats, Brooklyn Bot. Garden (USA): Vol 4 (1), Dec: 3 – 26.ISSN 1541-7115; http://www.urbanhabitats.org/v04n01/berlin_full.html

[8] Ksiazek-Mikenas, K., John Herrmann, Menke, S.B., Köhler, M., 2018. If You Build It, Will They Come? Plant and Arthropod. Diversity on Urban Green Roofs Over Time. Urban Naturalist. Special Issue No 1: 52-72. ISSN # 2328-8965 https://www.eaglehill.us/URNAonline/URNAspecialissues.shtml

[9] Kouvelis, K. 1978: Strategien für Kreuzberg. SenBauWohn Berlin (Hrsg.), Eigenverlag,16 S.

[10] Köhler, M. and Kuievda, N. 2015: Praxiserfahrungen mit den Ökohäusern. Dach und Grün 3:2015: 6-11. ISSN 0943-5271.

[11] Harms, M. 2016: Urban gardening an Fassaden und Dächern der Wohnsiedlung "Am Irissee" in Berlin. Bachelor thesis, Neubrandenburg.

[12] Shan, X.; Melina, A.N.; Yang, E.H.; 2018: Impact of indoor environmental quality on students' wellbeing and performance in educational building through life cycle costing perspective. Journal of Cleaner Production 204: 298-309.

[13] Tan, Y.; Liu, G.; Zhang, Y.; Shuai, C.; Shen, G.Q.; 2018: Green retrofit of aged residential buildings in Hong Kong: A preliminary study. Building and Environment 143: 89–98.

[14] Koc, C.B.; Osmond, P., Peters, A.; 2018: Evaluating the cooling effects of green infrastructure: A systematic review of methods, indicators and data sources. Solar Energy 166 (2018) 486–508.

[15] Shan, M.; Hwang, B.G.; 2018: Green building rating systems: Global reviews of practices and research efforts. Sustainable Cities and Society 39: 172–180.

[16] Khoshbakht, M.; Gou, Z.; Lu, Y.; Xie, X.; Zhang, J.; 2018: Are green buildings more satisfactory? A review of global evidence. Habitat International 74: 57–65.

[17] Ding, Z.; Fan, C.; Tamb, V.W.Y.; Bian, Y.; Li, S.; Chethan, I.M.; Illankoon, S.; Moon, S.; 2018: Green building evaluation system implementation. Building and Environment 133: 32–40. 19340.

[18] Chan, I.Y.S.; Liu, A.M.M.; 2018: Effects of neighborhood building density, height, greenspace, and cleanliness on indoor environment and health of building occupants. Building and Environment 145: 213–222.

[19] Alwisy, A.; BuHamdan, S.; Gül, M.; 2018: Criteria-based ranking of green building design factors according to leading rating systems. Energy & Buildings 178: 347–359.

[20] Vijayaraghavan, K.; 2016: Greenroofs: A critical review on the role of components, benefits,

limitations and trends. Renewable and Sustainable Energy Reviews 57 (2016) 740–752.

[21] Parris, K.M.; Amati, M.; Bekessy, S.A.; Dagenais, D.; Frydd, O.; Hahs, A.K.; Hes, D.; Imberger, S.J.; Livesley, S.J.; Marshall, A.J.; Rhodes, J.R.; Threlfall, C.G.; Tingley, R.; van der Reee, R.; Walsh, C.J.; Wilkerson, M.L.; Williams, N.S.G.; 2018 The seven lamps of planning for biodiversity in the city. Cities xxx (xxxx) xxx–xxx.

[22] Gracia, A.D.; Navarro, L., Coma, J., Serrano, S., Romaní, J., Pérez, G., Cabeza, L.F.; 2018: Experimental set-up for testing active and passive systems for energy savings in buildings – Lessons learnt. Renewable and Sustainable Energy Reviews 82 (2018) 1014–1026 19090

[23] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) 2018: White Paper: Green Spaces in the City. Green Spaces in the City – For a more livable future.

INTERNET LINKS: [IN BRACKETS FROM 1-1 TO 1-31]

[1-1] BFF Biotopflächenfaktor, Habitat area factor https://www.berlin.de/senuvk/umwelt/landschaftsplanung/bff/
[1-2] GDF, Green density factor, https://www.baufachinformation.de/gdf-green-density-factor-and-gcf-green-cooling-factor/buecher/248080
[1-3] C2C https://c2c-ev.de/
[1-4] Ken Yeang https://www.hamzahyeang.com/
[1-5] Emilio Ambasz https://www.ambasz.com/
[1-6] James Todd http://www.toddecological.com/
[1-7] Garry Baverstock http://ecotect-architects.com/
[1-8] Eco Pioneer of Earthwork architecture: Engelbert Kremser: http://www.engelbertkremser.de/Architektur.html
[1-9] Eco-Pioneer Martin Küenzlen in Berlin: https://www.engelhardt-kueenzlen.de/Vita_Martin_Kueenzlen
[1-10] Fallow Land "Brachen of Berlin", a film: https://www.naturaurbana.org/
[1-11] Martin Wagner: https://de.wikipedia.org/wiki/Martin_Wagner_(Architekt)
[1-12] Bruno Taut: https://de.wikipedia.org/wiki/Bruno_Taut
[1-13] Interbau, short IBA 1957: https://de.wikipedia.org/wiki/Interbau
[1-14] https://de.wikipedia.org/wiki/Alvar_Aalto
[1-15] https://de.wikipedia.org/wiki/Le_Corbusier
[1-16] https://de.wikipedia.org/wiki/Oscar_Niemeyer
[1-17] IBA https://de.wikipedia.org/wiki/Internationale_Bauausstellung_1987
[1-18] Symposium Ecological projects Berlin; IBA 30. Oktober 1980: https://fhxb-museum.de/xmap/media/S7/T1791/U25/text/fhxb_spk_gutber_01132_72.pdf
[1-19] Frei Otto https://de.wikipedia.org/wiki/Frei_Otto
[1-20] Eco houses, Rauchstr. 1984 https://www.engelhardt-kueenzlen.de/Corneliusstrasse
[1-21] Ökohaus Rauchstr.: https://www.wohnprojekte-portal.de/projekte-suche/projektdetails.html?uid=20273
[1-22] Several reprints of Berlin-Kreuzberg, IBA; available: https://berlin.museum-digital.de/index.php?t=listen&persinst_id=21482&oges=6599&cachesLoaded=true
[1-23] Information about the ufa: https://www.ufafabrik.de/en
[1-24] Thomas Herzog https://de.wikipedia.org/wiki/Thomas_Herzog
[1-25] Erich Schneider-Wessling https://de.wikipedia.org/wiki/Erich_Schneider-Wessling
[1-26] Otto Steidle, https://de.wikipedia.org/wiki/Otto_Steidle
[1-27] Peter Stürzebecher, https://www.baunetz.de/meldungen/Meldungen-Zum_Tod_von_Peter_Stuerzebecher_2489451.html
[1-28] Bernd Faskel, https://www.tagesspiegel.de/berlin/bernd-faskel-seine-projekte/1357040.html
[1-29] Bill Mollison, https://de.wikipedia.org/wiki/Bill_Mollison
[1-30] Declan Kennedy, https://declan.de/en/home-new/
[1-31] https://www.tagesspiegel.de/berlin/klimafreundliche-stadtentwicklung-wer-hat-das-schoenste-gruendach-in-berlin/22986608.html

Pictures by Manfred Koehler: 2a, 2b, 4a, 4b, 4c, 4d, 5a, 5b, 7a, 7b, 8a, 8b, 10a, 10b, 11a and11b

Edmonton Federal Building 2016 Interior Green Wall – Award Winner: Nedlaw Living Walls

The Bio-filter Living Wall system at the Edmonton Federal Building is the focal point of the large glass public atrium, the newly added grand entranceway into this rejuvenated historic building. The living wall and associated water feature provide a calm and serene environment in the busy public space. The vibrant layered and organic pattern of the plants makes the wall a work of art, and provides a foil for the otherwise angular and clean-lined space.

CHAPTER 14

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

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

INTRODUCTION

I first heard about green roofs in 1996 at a conference I organized on financing municipal environmental management. I was intrigued by the potential of green roofs to be widely implemented, as well as the ability to provide diverse public and private benefits. While roofs in our major cities are mostly wasted, underutilized spaces, greening these areas helps mitigate many issues urban cities face. 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, improve the habitat, clean the air, are self sufficient in water use and treatment, are beautiful and healthy for occupants and even produce food.

In 2012, our industry association, Green Roofs for Healthy Cities (GRHC) 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. At this point, it doesn't look like we are going to achieve this goal (in part thanks to the 2008 Recession), but we are still seeing a steady growth in the industry each year. 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, public policy or professional training. We have been able to take advantage of many policy opportunities and important drivers, such as the need to manage stormwater more effectively. We have also tapped into humanity's basic, most fundamental biophilic 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. Biophilic design practice is emerging from the science of how we react, both mentally and physically to our environment. Certain features, such as natural light, the sound of water and plants help to restore us and maintain our health. Other features, such as noise, sharp objects, artificial light and the absence of vegetation actually harm us, causing stress and undermining our health and well being. Increasing focus on human health and well being, in both the planning and building profession is the latest development in North America, with the introduction of the Well Standard and greater inclusion of health-related elements in the USGBC's LEED program of voluntary standards.

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, more social justice
Water conservation	Additional recreational opportunities
Reduction in associated health care costs from improving air quality and reducing heat	Greater community cohesion resulting in less vandalism
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 and the sound of water
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

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

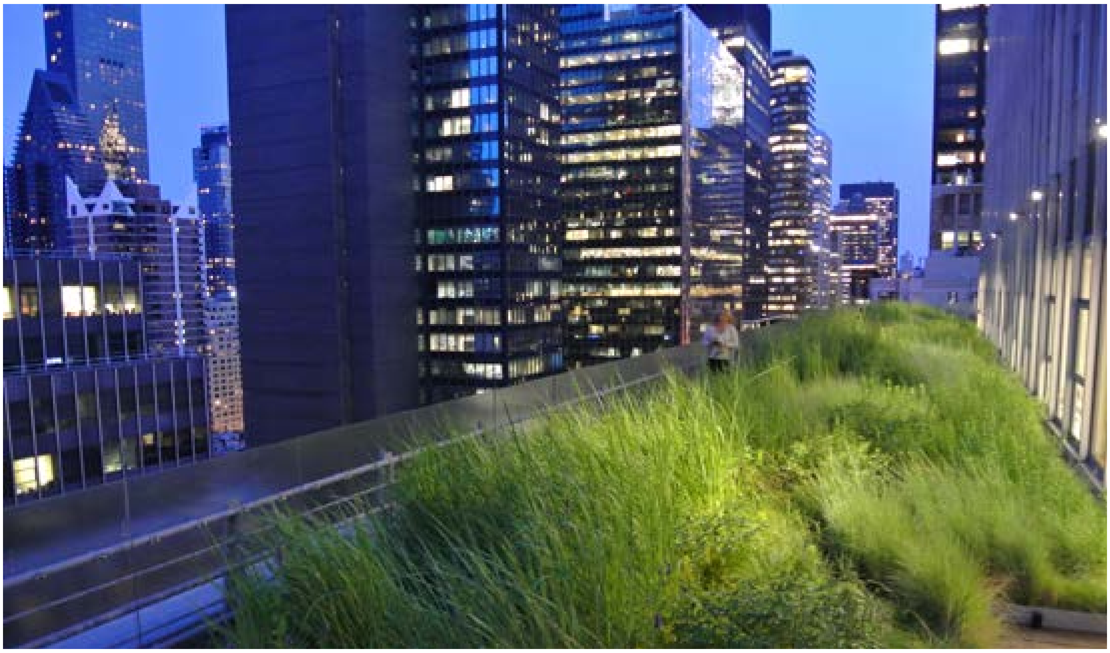
URBAN FOOD PRODUCTION RESULTING IN:	INCORPORATION OF GREEN PRODUCTS AND SYSTEMS RESULTING IN:
Greater food security	Improved markets for recycling plastics
Better food quality	Improved markets for compost and recycled aggregates
Increased employment	Lower emergy in overall system ie., less energy used at each stage in the life cycle
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.greenroofs.org/greeninfrastructurestore/)

EARLY HISTORY OF DEVELOPING GREEN ROOFS FOR HEALTHY CITIES AND THE GREEN ROOF AND WALL INDUSTRY

In 1997, Dr. Brad Bass, a scientist with Environment Canada and I, the principal consultant at then Peck & Associates, a policy consulting firm, applied for research 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 blueprint for developing the industry in North America – "Green Backs from Green Roofs: Forging a New Industry in Canada". This report utilized data on green roof benefits, largely from Germany and translated by Monica, and interviews with a few leading companies working in this field and the design community. It laid the groundwork for Green Roofs for Healthy Cities, a coalition of companies I brought together to develop the first Canadian Research and Demonstration project in Toronto. This work led to a demonstration project and ultimately the first mandatory policy for green roofs in North America, as well as a very successful conference in Chicago in 2003. This conference ultimately laid the groundwork for the establishment of the more formal non-profit industry association in the US 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. The key principles involved in our development, as well as the programs and resources we have developed in support of the industry since then, are described in detail below.



Midtown High Rise – 2014 Extensive Industrial/Commercial Winner – Award Winner: New York Green Roofs

Transforming a corporate office building into a lush green oasis in midtown Manhattan, this green roof offers staff of a booming realty company an unusually peaceful respite amidst the constant movement of a bustling city. 7,000 square feet of living roof and integrated decking establishes a buffer between a busy office space and one of the densest urban environments on the planet. The design provides a view upon ecological succession of a changing landscape as it incorporates a mostly extensive mix of meadow grasses, flowering perennials and low growing succulents.

This will hopefully be useful to people who are interested in advancing living architecture in their own countries through association work as wall as those working to design and implement green roof and wall projects.

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 and its charitable arm, the Green Infrastructure Foundation. 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 Eastview Community Center not only produced important data on energy savings and stormwater management, 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 undertaking research on all aspects of green roofs, from individual plant species survival to how to model reductions in the urban heat island effect. More recently, we have seen a healthy increase in green wall research on water and energy performance, having completed a collective research project in partnership with corporate members such as greenscreen, Carl Stahl and Jakob Rope

Systems who supply green facade technologies, those that support climbing vines growing away from the building envelop.

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*, now in its 17th year, we have a dedicated series of speakers on the latest research developments, where all their work must go through a peer review process run by scientist volunteers. Exceptional papers are published in the online *Journal of Living Architecture* (JLIV). We also use *CitiesAlive*, which moves around North America, to reach out to policy makers in different jurisdictions to raise awareness of the need for policy support of green roofs and walls.

Estimates of Public Benefits from Green Roof Installation in CDN$ 2012 /square meter

Benefit	Value ranges $/m^2	Studies that considered it
Stormwater infrastructure cost reduction due to volume reduction – Capital	$0.3 to $45.9	Toronto, Portland, Tomalty, Clarke, SoCal
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, SoCal
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).

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 designers 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.

In our free, quarterly digital magazine, the Living Architecture MonitorTM, we publish exceptional green roof and wall 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 the very best papers in the field of living architecture research each quarter. Under the leadership of Rohan Lilauwala, GRHC, and Dr. Reid Coffman, 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.

Journal of Living Architecture, Founding Editorial Board Members

Chair, Dr. Robert Berghage, Penn State University, USA
Dr. Reid Coffman, Kent State University, USA
Dr. Nigel Dunnett, University of Sheffield, UK
Dr. Brad Bass, Environment Canada), CDN
Dr. Sabina Shaikh, University of Chicago, USA
Dr. Bill Retzlaff, Southern Illinois University Edwardsville, USA
Barry Lehrman, March/MLA, California State Polytechnic University, Pomona, USA
Dr. Maureen Connelly, British Columbia Institute of Technology, CDN
Dr. Youbin Zheng, University of Guelph, CDN
Dr. David Tilley, University of Maryland, USA
Thomas O'Connor, MSE, US Environment Protection Agency, USA
Dr. Bradley Rowe, Michigan State University, USA
Dr. Richard Sutton, University of Nebraska-Lincoln, USA
Bruce Dvorak, MLA, Texas A&M University, USA
Dr. Jennifer Bousselot, Iowa State University & Colorado State University, USA
Virginia Russell, MLA, University of Cincinnati, USA

See: https://greeninfrastructurefoundation.org/jliv/

REGIONAL CENTERS OF LIVING ARCHITECTURE EXCELLENCE PROGRAM LAUNCHED IN 2018

In 2018, we held a competition to solicit bids from academic institutions to formally partner with GRHC to promote education, research, product development and policy in different regions of North America. Seven academic institutions, located in Colorado, New Jersey, Illinois and Ohio have been selected to establish the first four Centers for Regional Living Architecture Excellence. This program is very new and details are being worked out regarding each Center. The basic concept is to try to integrate research, pedagogy, industry and policy development together more effectively in order to advance the industry in each region and provide a supply of qualified employees.

The leading academic partners and the lead academics for each Center are as follows:

Illinois

Southern Illinois University Edwardsville, Dr. Bill Retzlaff, Associate Dean, CAS, Distinguished Research Professor, Biological Sciences

New Jersey

Stevens Institute of Technology, Dr, Elizabeth Fassman-Beck, Associate Professor, Department of Civil, Environmental and Ocean Engineering

Colorado

Colorado State University, Dr. Jennifer Bousselot, Special Assistant Professor, Department of Horticultural and Landscape Architecture; University of Colorado Denver, Leila Tolderlund, Assistant Professor, College of Architecture and Planning.

Greater Ohio

Kent State University, Dr. Reid Coffman, Associate Professor, College of Architecture and Environmental Design; University of Cincinnati, Professor Virginia Russell, Director, Horticulture/Landscape Architecture/ Professor Landscape Architecture and Dr. Ishi Buffam, Department of Biological Sciences; Heidelberg University, Mark E. Mitchell, Biological and Environmental Sciences.

LIVING ARCHITECTURE PERFORMANCE TOOL (LAPT) LAUNCHED IN 2018

Despite its many benefits, living architecture (green roofs and walls) is complex and varied, and this complexity leads to many barriers. Inconsistent policy, a lack of accepted performance benchmarks, and a lack of representation of living architecture in existing building rating systems (LEED, SITES, etc.) are obstacles that hinder the widespread use of living architecture. Hence, there is much work to be completed in the field of green roof and wall performance. For the past six year, GRHC and GIF have been 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. After publishing a series of White Papers that reviewed the science and policy in different areas, like water, energy, human health and well being, and the frameworks of the USGBC's LEED program and Sustainable Sites, a draft framework was produced in 2017 for review by experts.

The Living Architecture Performance Tool (LAPT) Version 1.0 was finally launched in 2018 with our expert co-chairs, David Yocca of Biohabitats, and Lois Vitt Sale, of Wight and Company. The Living Architecture Performance Tool (LAPT) is a rating system and resource, designed to certify that green roofs and walls are designed to achieve certain measurable and replicable performance benefits, so that they can be funded, designed, installed, and maintained with a higher degree of confidence. The LAPT is also designed to inform voluntary green rating systems like the United States Green Building Council's (USGBC) LEED programs, Sustainable Sites and the Living Building Challenge, which do not always recognize the full spectrum of benefits provided by these technologies.

In 2018, the LAPT Version 1.0 was released, and twenty-five pilot projects from different regions are encouraged to participate. The LAPT is a 110-point system, encompassing 30 credits in 8 major areas of living architecture performance. It is designed to be robust and comprehensive, low cost and yet easy to use with a streamlined compliance process.

The LAPT contains a total of 110 points that a project could theoretically achieve. 100 are base points and 10 are innovation points recognizing the rapid evolution of green roof and wall technologies. The levels of potential certification are: LAPT Certified – 40+ points / LAPT Silver – 50+ points / LAPT Gold – 60+ points / LAPT Platinum – 80+ points.

A basic but well designed and maintained sedum based extensive green roof should be able to achieve enough points to become certified under this system. Gold and Platinum green roofs and walls will have to provide a wide number of benefits as wall as system integration with other building systems. The use of integrated design processes, and clearly defined maintenance plans and budgets for five years are prerequisites for any type of LAPT certification. The LAPT is designed to provide buildings owners with

Living Architecture Performance Tool Pilot Phase: Focus Areas, Credits & Points (2018)

Focus Area/Credit	Points: 110
1. Process	5
1.1 Integrated Design Process	Prerequisite
1.2 Stakeholder and Community Engagement	3
1.3 Living Systems Expertise	2
2. Water Management	25
2.1 Stormwater Management	Prerequisite + 16
2.3 Irrigation	5
2.4 Water Balance	4
3. Energy Conservation	14
3.1 Envelope Thermal Moderation	5
3.2 Urban Heat Island Reduction	4
3.3 Renewable Energy	2
3.4 HVAC Integration	3
4. Habitat and Biodiversity	11
4.1 Plants	4
4.2 Growing Media Depth and Composition	2
4.3 Habitat Elements	2
4.4 Biomass	3
5. Health and Well-Being	21
5.1 Biophilic Design – Visibility	2
5.2 Biophilic Design – Accessibility	4
5.3 Food Production	10
5.4 Air Quality Improvements	3
5.5 Acoustics	2
6. Materials and Construction	14
6.1 Structural Soundness	Prerequisite
6.2 Environmentally Sensitive Materials	3
6.3 Sustainable Materials	3
6.4 Construction Waste Management	2
6.5 Equity-Focused Sourcing and Hiring	3
6.6 Bird-Friendly Glass	3
7. Post-Construction	10
7.1 Operations and Maintenance	Prerequisite + 2
7.2 Fertilizer and Pesticide Use	2
7.3 Monitoring	3
7.4 Education	3
8. Innovation	10
8.1 New Approaches or Strategies 8.2 Exemplary Performance	10
TOTAL	110

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).

greater assurance that the projects they have requested will deliver the benefits they are seeking. An overview the LAPT framework is provided in the table below. For more information and to download the LAPT please visit www.greeninfrastructurefoundation.org

The pilot phase of this program offers a limited number of innovative and forward-thinking organizations a chance to participate. Getting involved will help you optimize the range of benefits possible from your projects, demonstrate leadership and innovation, set the stage for long-term performance of your projects, received recognition in the marketplace, and receive personalized support through the process. Benefits and pricing from the pilot phase may not be offered in future phases of the LAPT. The pilot phase concludes at the end of 2019.

Projects across North America that use green roofs, green walls, and combinations of the two are eligible to participate. New projects, projects in any phase of the design or construction process, or projects completed in the past five years are eligible in the pilot phase. Organizations involved in the project in any way (designers, building owners, product manufacturers, etc.) are eligible to apply, as long as they have access to the required documentation.

The LAPT can be used as a best practice tool to optimize the breadth and depth for the design, installation, and maintenance of green roofs and walls. By demonstrating the linkages between benefits and encouraging holistic thinking, it is possible to obtain many additional benefits without significantly increasing cost or difficulty of many projects. The LAPT can also position your organization as a sustainability leader, recognizing your organization as innovators and leaders in the field.

The LAPT is designed to be used as a guideline or decision-support tool by policy makers. Policy makers that want to optimize the public benefits provided by green roofs and walls but do not have the in-house expertise or capacity to ensure compliance are an ideal audience for the LAPT. For more information on how to best use the LAPT in your community, contact us.

The LAPT document contains a detailed description of the principles, objectives, and intent of each performance area and credit, along with performance levels, weight of each credit, compliance requirements, strategies for compliance, and additional resources.

To learn more about the program, participate in the pilot phase, or download the full version of the LAPT document, visit www.greeninfrastructurefoundation.org

DEVELOPING POLICY SUPPORT

Experience in Europe, particularly Germany, demonstrates that there are multiple public benefits (in addition to private benefits) which stem from green roof and wall implementation. Furthermore, the green roof, and to a lesser extent green wall, industry enjoyed significant growth when local governments established financial incentives, and in some cases implemented requirements for green roof construction in new and existing buildings. It's no surprise that the leading jurisdictions for green roof implementation each year are those with mandatory requirements and or regulations that support green roof implementation. Toronto, Washington, New York and Chicago are typically in the top five metropolitan jurisdictions for the most green roofs implemented each year.

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 40 of these events, and we have seen the adoption of green roof incentives and policies in a number of important markets. In addition, more than 80 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.

The table below provides an overview of policy developments in North America.

Each year, at our annual CitiesAlive conference, we have an award that is presented to a government official or a political leader to recognize their support of green roof policy in addition to a research excellence award and awards for outstanding green roof and wall projects. These awards are promoted online and in our Living Architecture Monitor magazine and have helped us secure the

Dedicated North American Green Roof and Wall Policies, As of 2018

City	Name of Policy	Date
New York City	Green Infrastructure Grant Program	2011
Washington, DC	Stormwater credit trading	2014
Austin	Downtown Density Bonus Program	2014
Philadelphia	Amending Title 14 of The Philadelphia Code, entitled "Zoning and Planning," by providing special density rules for buildings with a green roof, under certain terms and conditions.	2015
Prince George County, MD	Rain Check Rebate Program	2015
Chicago	Chicago Zoning Ordinance Green Roof Incentives	2015
Philadelphia	Green Roof Tax Credit	2016
Washington, DC	Green Roof Rebate Program	2016
Nashville	Green Roof Rebate Program	2016
Saint-Laurent, Montreal	Règlement sur le zonage no RCA08-08-0001	2016
San Francisco	Better Roofs Ordinance	2017
Denver	Denver Green Roof Initiative	2017
Milwaukee	Milwaukee Metropolitan Sewage District Green Roof Initiative	2017
Palo Alto	Stormwater Measures Rebate Program	2017
Washington, DC	Stormwater fee rebate	2017
Washington, DC	Green area ratio	2017
Minneapolis	Chapter 510 of Minneapolis Code of Ordinances (Stormwater Management System and Operations of a stormwater management utility	2017
Portland	The EcoRoof Requirement (Portland Central City 2035)	2018
Syracuse	Onondaga County's Green Improvement Fund	2018
Guelph	Stormwater Credit and Rebate Program	2018
Montgomery County, MD	RainScapes Rewards Rebate Program	2018
DC	RiverSmart Landscaping Rebates	2018
Fort Wayne, Indiana	Catching Rain Green Infrastructure Initiative	2018

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

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 for the latest survey information).

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.

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 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.

Toronto

Chicago, Toronto and Washington DC, have since been leading cities in their support of green roofs. Both Chicago and Toronto led the market by requiring their own buildings to implement green roofs as well as the many agencies, boards and commissions under its control. Using the procurement power of the local and regional governments is a great way to get the industry started locally.

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. Revenue generated from these fees is used to provide funds to existing building owners as an incentive to develop green roofs. Given that there are a number of very tangible benefits that are available to building owners from green roof implementation (See table below), 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.

Over the past ten years, the green roof policies and program in Toronto and subsequent building boom have resulted in more than 6 million square feet of additional green roof space permitted in the City, the equivalent of four large city parks as of 2017. Toronto was 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).

There are very few opportunities for policy makers to achieve multiple public benefits, through the development and redevelopment process, in a manner that leverages private roof and wall space, as well as investment. Since there are many private benefits from green roofs and walls, there tends to be less resistance to policies that incent or require these technologies. Green roofs are the perfect public-private partnership, in that they confer many public and private benefits, while exploited large areas of wasted roof and wall space in our cities. In 2017, The City of San Francisco became the first US city to mandate the use of green roofs (30% roof area) and/or solar panels (15%) on new construction projects. During the development of its mandatory green roof/solar panel requirement for new buildings, called the Better Roofs Ordinance, developed a number of studies that costed out the public and private benefits. See https://sf-planning.org/san-francisco-better-roofs for more information

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 below. Since this study was undertaken, the costs of extensive green roof design and implementation have gone down, in some cases by as much as 30 per cent.

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 photovoltaic 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

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.

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 or '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 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. 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

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 CO2, $/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

Breathe Wall – 2015 Exterior Green Wall – Award Winner: LiveWall

Entitled 'Breathe', this living art project at ArtPrize®, the world's largest publicly voted art contest, is home to more than 3500 plants and reaches over 20 feet tall at its peak and stretches 150 feet long. Using the LiveWall® system as the canvas, the entry surrounds and buffers the noise and odors of the city around it. 'Breathe' was inspired by the idea of restoring the built environment to a more natural state and restore balance to urban settings by reintroducing vegetation lost during urbanization.

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 2019, we organized our 7th conference entitled Grey to Green: Adapting to Climate Change in Toronto with over 400 delegates from across North America in attendance. Conferences remain an important vehicle for exchanging ideas and promoting green infrastructure to a wider audience.

As a result of lobbying by GIO members, green infrastructure has now been incorporated as a requirement in local and regional government asset management report, meaning that governments will have to develop methods to assess the quantity and quality of their green infrastructure assets, such as urban forests, bioswales, green roofs etc. by 2022. See www.greeninfrastructureontario.org for resources and information.

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:

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

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

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

o 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.

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

o 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 900 accredited GRPs in the market. These core training courses are now provided through online, internet based training is now available online 24/7/365, thereby avoiding the cost of travel and accommodation to take a sit-down exam, which is also available online. Successful GRPs must remain members in good standing with GRHC and complete 16 hours of related training each year to remain current with industry developments and maintain their GRP accreditation.

In support of continuing education, 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, Green Infrastructure Valuation*, 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. Online training is available at www.livingarchitectureacademy.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)

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, but as the sector has developed in North America, there are more dedicated green roof and wall companies 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.livingarchitecturemonitor.com). Manufacturers also play an important role in supporting research and development activities, product and process innovation, and ongoing education of the design community.

CONCLUSION

The intense greening of cities is a proven approach to addressing many of the impacts of climate change, and the ongoing need to focus on human health and well being. Intensive greening 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. They need to have experience with nature, and knowledge about how it benefits them in their daily lives. This provides the basis for the political support.

Rooftop Wheat Prarie – 2017 Extensive Industrial Commercial – Award Winner: Omni Ecosystems

Chicago's Rooftop Wheat Prairie is a unique, picturesque landscape growing three stories above a bustling Chicago intersection. A complete anomaly in aesthetics and general design, it is the only rooftop in the city growing amber waves of grain. The golden wheat accented by bright wildflowers offers city dwellers a one-of-a-kind visual splendor. To immerse visitors into the wheat prairie, a room of floor-to-ceiling glass windows was constructed in the middle of the roof, offering incredible views from all angles.

During the Denver Green Roof Ballot in 2018, the people of Denver voted 54 per cent in favor of mandatory requirements for green roofs on new buildings, despite a well funded opposition campaign to discredit the benefits of green roofs in the city. If you live in a city that has a green infrastructure foundation, like the valleys and ravines in Toronto or major parks, or a regional forest, these resources are a major asset that you can build upon in order to implement living architecture in, on and around our buildings. In many parts of the world, it is important to protect these resources from corruption and unplanned development, and then to work on expanding greener in our cities for the benefit of all.

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. The gradual adoption of the Living Architecture Performance Tool, by designers and policy makers will help to improve the performance of green roof and wall systems in the years to come.

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

Van Dusen Botanical Garden – 2017 Extensive Institutional – Award Winner: Connect Landscape Architecture & Architek

The state-of-the-art Visitor Centre re-connects people to the environmental issues of the 21st Century including water and energy conservation, re-use and recycle, beauty of our native plant ecology, and a healthier way of building and design. The overall scope was 5 acre site master plan including a 16,000-ft2 green and blue roof.

Harvard Business School's McArthur/McCollum Building Rooftop Meadow – 2018 Extensive Institutional – Award Winner: Recover Green Roofs

Across seven sections of a multi-tiered roof on Harvard Business School's McArthur/McCollum building stretches an 11,000 ft² extensive meadow. The design team searched for an innovative solution that would be light enough to satisfy weight restrictions for the building while showcasing a highly visible and structurally complex roof.

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 are working 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.

ABOUT THE AUTHOR:

Steven W. Peck, GRP, Honorary ASLA, is the founder and president of Green Roofs for Healthy Cities (GRHC), the North American green roof and wall industry association.

Early in his career he worked as a public policy consultant and examined barriers to sustainable community development and the role of governments in supporting environmental technology development and diffusion. Since 1996, he has worked to advance the green roof and wall industry by facilitating research and demonstration projects; organizing conferences and workshops; writing articles; judging awards competitions; building institutional capacity; lecturing; publishing and advocating for supportive policies and standards at all levels of government.

In 1999 he began editing and publishing a quarterly green roof and wall magazine *entitled Living Architecture Monitor™ (www.livingarchitecturemonitor.com). Mr. Peck has written and lectured extensively on the interrelationship between public policy, research and the socioeconomic benefits of living architecture, as well as on the topics of urban sustainability and industrial ecology.*

In 2007 he co-founded the Green Infrastructure Foundation, the charitable arm of GRHC, with Michael Krause, which is dedicated to advancing all forms of green infrastructure. In 2010 Mr. Peck co-founded the Green Infrastructure Ontario Coalition in 2010 with Janet McKay of LEAF in order to lobby for living green infrastructure protection and investment in the Province of Ontario.

Author of Award Winning Green Roof Designs (2008), Mr. Peck has spearheaded the development of the accredited Green Roof Professional (GRP) program and has co-written and/or edited the following resource manuals: Green Roof Design 101: Introductory Course (2004); Green Roof Design and Installation 201 (2006);

Green Roof Policy Development (2006); Ecological Green Roof Design (2006); Green Roof Waterproofing and Drainage 301 (2007); Green Walls 101: Systems Overview and Design (2007); Green Roof Plants and Growing Media 401 (2008); Green Infrastructure: Policies, Performance and Projects (2009); Introduction to Integrated Water Management for Buildings and Sites (2010); Introduction to Rooftop Urban Agriculture (2010); and

Advanced Green Roof Maintenance (2011). Co-Developer, Living Architecture Performance Tool V. 1.0 (2018); Co-Author, Living Architecture Performance Tool (2018)

In 2007, he co-founded the World Green Infrastructure Network, with Dr. Manfred Koehler, an international coalition of green roof and wall associations dedicated to developing the living architecture industry world-wide (www.worldgreenroof.org). In 2012 he produced and edited The Rise of Living Architecture which celebrates the many projects and people that have developed the green roof industry in North America, and provides insights into future trends and developments.

Mr. Peck remains optimistic about our ability to, within a generation, rapidly evolve the building industry towards producing restorative buildings and communities using green roof and wall technology.

Toledo
civitatis
civitatis

Green wall. Madrid.
Belén Gonzalez Blanco

CHAPTER 15

A BRAZILIAN GREEN ROOF STORY: HOW TO GET TO THE NEXT LEVEL?

Sérgio Rocha
CEO. Instituto Cidade Jardim

SUMMARY

In Brazil, green roofing started to gain force in the late 2000's with the first specialized companies offering products and services to the market. Although green roofing did not take off as a big business in the country, we have an incipient industry that has consistently delivered a 100 thousand square meter per year. However, without governmental aid this market has not grown in the last 10 years. We are proposing the internet as a tool to extend green roof education to a wider audience and the development of more suitable and economic technologies to attract business. An example is a new single-ply hydroponic sandwich panel that promises to replace ceramic tiles and could represent a next generation product to popularize green roofing, positioning them to compete in the wider roof market.

KEYWORDS

Green roof, rooftop gardening, Brazil, permaculture, green building, sandwich panel, hydroponics.

INTRODUCTION AND GOALS

When Burle Marx installed his first roof garden in Rio de Janeiro during the effervescent 1930's, he was making Brazilian history. The modern green roof movement had just been born in Europe, and with this introduction he inspired a whole generation of projects in different Brazilian regions during the next decades. The terrace gardens of the Gustavo Capanema Palace, in Rio de Janeiro, represent one of the few well preserved examples of this period. Inaugurated in 1938, were declared a National Historical Heritage three years after opening. Another historical landmark from the same period is the Matarazzo Building (also known as the Anhangabaú Palace), in São Paulo. Opened in 1939, it was built to be the headquarters of the Matarazzo textile company. The project of the Italian architect Marcello Piacentini has a green roof with more than 400 trees and a fish pond a top a 14-story building. Today, the Anhangabaú Palace houses the São Paulo City Hall, which organizes guided tours for those wishing to visit one of the oldest green roofs in the country - and be presented with a beautiful view of the city.

Different from Germany where green roofs have been developed technically and politically, reaching the status of an urban transformation tool early in the 1980's (with the impressive score of 8 million square meters installed and € 254 million in sales only in 2015), in Brazil, green roofing has remained as a decorative item. The idea of making it popular and escalating it to help fix urban deficiencies started to gain force after the 1990's with the arrival of the permaculture movement in the country.

It's not our objective to write a definitive story about green roofs in Brazil, but to present our views and perspectives after 10 years of the Instituto Cidade Jardim, and also to contribute to the movement. I would like to thank all professionals and activists who collaborated towards this goal also.

METHODOLOGY, CONTENT AND DESCRIPTION

In order to a build a scenario that is clear and fluid for everyone trying to understand the Brazilian green roof market, I will draw a timeline perspective of the main actors in this game - companies, professionals, NGOs, investors, education, political environment and innovation - starting from the grassroots movement that helped put green roofs on the socio-environmental agenda in this country - and brought us to this business.

PERMACULTURE: GREEN ROOF AS A TOOL, A MULTIFUNCTIONAL ELEMENT FOR MICRO AND MACRO INTERVENTION IN CITY DESIGN

Coined by the Australian Bill Mollison in the 1970's and with a strong activist punch, permaculture is a design science for "agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems, (...) as a design system it contains nothing new. It arranges what was always there in a different way, so that it works to conserve energy or to generate more energy than it consumes." (Mollison 1988).

After the first design course taught by Bill Mollison in Porto Alegre, Brazil, in 1992, green roofs became elements in several permacultural designs in many rural sites - from hen houses to administrative offices. Permaculture institutes and demonstration centers strategically placed in the country started to spread the idea, although at a non-commercial scale. Indeed, the first really extensive green roof I saw in Brazil was in Manaus in 2003. It was a very rustic mix of grass and weeds grown in a thin layer of soil over a wooden rooftop. Built for technical performance, not for decoration or beauty, this green roof model could be seen covering several chicken coops and pig sties at the Amazon Permaculture Institute, where Fabiana Scarda and I (co-founders of Instituto Cidade Jardim) worked for Ali Sharif (from Permaculture Latin America) and Carlos Miller (from the AVINA Foundation - an international organization dedicated to connecting entrepreneurs from the third sector to the business sector). Working mostly with common techniques, those green roofs followed the primitive sod house concept adopted by permaculture manuals - earth, wood and stones, now combined with some modern industrial materials, such as plastic tarps, clay balls and filter fabrics. Despite the lack of technical depth compared to German FLL - Forschungsgesellschaft

Hospital da Restinga: Porto Alegre, Rio Grande do Sul (2017). Largest Green Roof Project - continuous area (5,963 square meter). Landscaper: Toni Backes Paisagismo; Installer: Marcelus Oliveira & Telhado Vivo Coberturas Verdes; Green Roof System: FLAT Instituto Cidade Jardim.

Landschaftsentwicklung Landschaftsbau (Landscape Development and Research Society) guidelines, the translation of the 'Barefoot Architect Manual' (van Lengen 1997) and 'Introduction to Permaculture' (Mollison 1998) into Portuguese introduced a new generation of young students to the idea, many of whom began to apply energy efficiency principles - and include green roofs - in their designs.

MARKET AND ESCALATION

Although some foreign companies, like Bidim and Maccaferri, were advertising their geotextile products for roof gardening (sometimes as a secondary use), it was only in 2005 that the first generation of green roof products appeared in Brazil to meet the market demand that was beginning to form. Ecotelhado, a former building company from Porto Alegre, played an important role in bringing a market-driven green roof package to an audience of civil engineers, architects and landscapers. With good transit among construction companies and investing in a nationwide network for distributing its products, they released a wide range of products in the next years within the themes of green infrastructure and biophilic design, including green roofs, green walls, bio-swimming pools and so on. They soon installed 60.000 square meters per year, and announced an average annual turnover of € 1.3 million in sales in 2018.

In 2007, we decided to leave the NGO world of permaculture centers to found the second green roof company in Brazil, based in São Paulo. Instituto Cidade Jardim was created to combine business, research and activism, designed as a private research institute focused on green roofing material development and market promotion. We developed our own family of products and services, and installed about 10.000 square meters per year with an annual turnover of € 400 thousand in 2015. Our differential is exactly in this mixed approach, so what really makes our eyes shine is urban farming and the chain reaction it can inspire. We wanted to show that permaculture energy efficiency strategies can be applied to the urban environment, so we chose to focus much of our efforts on the development of techniques and technologies for the production of food on slabs and rooftops, and the connections of these activities with other elements in the functioning of the building.

Since 2011 we have been experimenting with the cultivation of agricultural commodities (grain carbohydrates such as wheat, beans and maize) on slabs and lighter roof prototypes, publicizing and promoting the benefits of growing food in scale within cities. At the level of subsistence horticulture, we have a demonstrative rooftop garden installed over Instituto Cidade Jardim headquarters in the center of town. Here we receive visits from students, researchers, clients and the press. Within a permaculture design, we produce from table grapes and strawberries to a large variety of leafy greens (several lettuce varieties, cabbage, arugula, almeirão, catalonha, broccoli), vegetables (tomatoes, pumpkins, zucchini, eggplant, chilli peppers), tubers (potatoes, yams, cassava, earth turmeric, carrots), herbs, spices and medicinal plants (basil, sage, rosemary, mint, mint, onion, chives, parsley, celery, coriander, lemon grass and chamomile, aloe, capuchin), as well as ornamental plants. All rain water that runs off of the green roof is collected into a swimming pool that has been transformed into a pond. With a diversity of aquatic plants, we grow a diversity of insectivorous and herbivorous fish species that feed on the algae and sediments formed by the residual nutrients. The organic sediment collected during pool cleaning is composted and used to feed laying hens. Finally, the manure is collected and redirected to fertilize the rooftop garden, closing the cycle.

The third company to enter the scene is Technes, a traditional growing-media producer founded in 1987, that in 2008 decided to compete in the green roof market and launched the new commercial brand, Skygarden, also in São Paulo. With strong marketing and media interventions, and with a secret technology brought from Japan, they easily reached a turnover of € 900 thousand in sales (Jaggi 2018 a). Working with geotextiles for drainage, they focus on special green roof and green wall substrates.

By the way, green walls rapidly became much more popular than green roofs in Brazil. Here I want to mention Movimento 90º, which also started as a third sector movement but shifted to a business model in 2013 to promote vertical greening for urban parks in São Paulo. They were responsible for the huge green walls along the Minhocão (an elevated avenue) and also for the 6 km green corridor along May 23rd Avenue (estimated at € 2,2 million), both in the center of São Paulo.

Many other professionals are building green roofs in their own ways. The 5.000 square meter green roof over the Eldorado Shopping Mall (in São Paulo) is the most famous one. The project began after agronomist Rui Signori (from the consulting company Ecoagro Academy) started his innovative composting program in the basement of the mall. Collecting all food waste from restaurants and bringing it to an enzyme-accelerated composting station he developed, they soon realized the need to find a proper destination for the compost. The rooftop was the obvious solution and now 5.000 square meters of vegetables and herbs are grown on the roof in reused plastic buckets and boxes. The Eldorado initiative was replicated on other shopping malls in Rio de

Janeiro, Belo Horizonte and Manaus, making it a benchmark throughout the country.

An outsider initiative I want to mention is Telhado Verde Favela, a grassroots project born in Rio de Janeiro. After spending an infernal summer in 2012, Luis Cassiano, a cultural activist and community leader, decided to install a green roof over his house in the 'Favela do Arará'. A close friend from ABIDES (a local NGO) opened the doors of his office to Luis, who started to research about green roofing on the internet. Through a common friend living in Berlin, he was presented to the botanist Bruno Rezende (from the Rio de Janeiro Botanical Garden), who was developing his thesis for a soilless green roof system to be installed over the zinc and fiber-cement tiles so common in favelas. Cassiano also articulates with ENACTUS (a world class NGO hosted by the Federal University of Rio de Janeiro) that helped with materials and technical support. Now they are mapping the local demand in order to establish a future business to be replicated for low-income communities. This is a hot subject, since it can positively affect large human communities living in the immense urban heat islands that are the favelas all around the world.

GREEN ROOF HUBS IN BRAZIL

In addition to the companies and organizations I mentioned above, there are some academic and activist Green Roof Hubs that I want to mention. Brazilian undergraduate and graduate students are already publishing about green roofs. There are several research groups in public and private universities throughout the country.

I will highlight two academic centers for their pioneering and ongoing work. The first is the work of Duarte Vaz and Pierre-André Martin in the company EMBYÁ, which, together with professor Cecilia Polacow Herzog (coordinator of the Postgraduate Program in Ecological Landscaping at the Pontifical Catholic University of Rio de Janeiro), offers the specialization course in "Ecological Landscaping: Landscape Planning and Design". This course includes a focus on green roof science and techniques. The second is the Laboratory of Floriculture (LaFlor) at the Federal Rural University of Pernambuco (UFRPE), coordinated by professor Vivian Loges. Prof. Loges coordinates undergraduate and postgraduate studies in Agronomy, Horticulture and Plant Science with a major focus on native plants for use as lawns, green roofs and urban landscaping, taking into account the beauty, conservation, identity of place, and low maintenance requirements for use in public areas.

With regard to activism, I would also like to cite the work of agronomist Tony Backes and engineer Marcelus Oliveira, at the "Perau do Encanto" Landscaping School, in Nova Petrópolis, Porto Alegre, Rio Grande do Sul, and that of landscape architect Maria Cecília Guinle, of "Vida no Teto", in Florianópolis, Santa Catarina. Tony and Marcelus teach about green roofs to hundreds of students in their regenerative landscaping course each year. They practice what they teach and are responsible for the landscaping project and installation of the largest modern green roof in Brazil, with 5,963 m2 of cultivated area, at the Restinga Hospital in Porto Alegre. In addition to designing and installing green roofs, Maria Cecília works with the landscaping nucleus of the Commercial and Industrial Association of Florianópolis, which launched the project that installed the first bus stop with a green roof in the capital of Santa Catarina. The initiative gained prominence in the national media and was later replicated on an experimental basis in other cities, such as Manaus (Amazonas), Salvador (Bahia), Garopaba (Santa Catarina) and Caxias do Sul (Rio Grande do Sul).

POLITICAL ENVIRONMENT

With advice from the World Green Infrastructure Network (WGIN), Ecotelhado founder João Feijó was probably the first person to systematically promote green roofing expansion in Brazil through governmental aid. To further this idea, he created (almost by himself) the first national association of green roofs, and toured the country, contacting municipalities and collaborating on green roof bills. Nonetheless, ATVB (Brazilian Green Roof Association and, later, Brazilian Green Tech Association) never became a representative entity for the green roofing industry in the country, nor did it connect to grassroots movements, such as permaculture, remaining as a single-company initiative. However, this does not mean that ATVB has had no impact.

Brazilian politicians were introduced to green roofs and quickly realized their potential to generate political capital and leverage personal popularity. Suddenly, green roof bills started popping up everywhere, and after 2008 a race took place to approve the first generation of municipal green-roofing laws - as fast as possible to gain political and media visibility.

One thing that catalyzed this race was the "One Degree Less" campaign by the Green Building Council Brazil (GBCB). Supported by the US Green Building Council, in February 2009, GBCB launched its national marketing initiative to promote cool roofing (white painting and green roofing) funded by Dow Chemical, BASF and Sherwin Williams. The marketing used celebrities with white paint on their hands, broadcasting promotional videos at cinemas and on TV, and organizing events. In the same year a white roof bill was presented to the São Paulo legislature, and, separately, a green roof bill, also in São Paulo, and then also at the Federal level. Because of poor drafting and the idea of mandatory installation, the proposals caused considerable controversy.

After several negative insertions in the media, these projects came under severe criticism. The first to oppose mandatory white roofing was the São Paulo Housing Union (SECOVI-

Ilha Pura Condominium: Rio de Janeiro, Rio de Janeiro (2016). Largest Green Roof Project - discontinuous area (10,031 square meter). Installer: Chácara Santa Clara Paisagismo; Green Roof System: FLAT Instituto Cidade Jardim.

SP), which in 2011 published a note arguing that roofs would have to be polished and sanded in order to receive paint, which represents asbestos and other waste strewn in the air in absurd amounts, given the size of the city. The Brazilian Council of Sustainable Construction (CBCS) also published their position against white painting, and in this same year CAU (Brazilian Council of Architecture and Urbanism) took a position at the Federal level against the green roof bill PL 1703/2011, but recommended substituting mandatory installation with financial, fiscal or credit incentives.

In 2011, GBCB tried an unsuccessful approximation with the three main Brazilian green roof companies, but the point is that the clever use of the term ‘cool roofs’ by the One Degree Less campaign, and the comparison between green roofing and white roof painting has created confusion in the market. They made a nonsense claim that white roofs are also green (because of thermal effects), positioning live green roofs as ‘cool’ technologies, but hard to work with and inaccessible to the majority of the population.

In this confused climate, in 2012 the city council of Rio de Janeiro proposed a mandatory bill (complementary project nº 89/2012) establishing that all new public and private buildings should be covered with green roofs. However, if they are unable to apply this option, they would be obliged to use white paint as an alternative solution. Again, the subject caused controversy and the proposition was archived.

In June 2014, the CBCS published its position against federal green roof bill PL 1703/2011, strongly criticizing the proposal that green roofing become mandatory in the country, because (1) they are not adequate to the different Brazilian climatic regions, (2) they lack solid supplier chains, (3) they may pose public health risks when poorly installed, (4) they have inaccessible costs for most residents, (5) they have high maintenance costs, (6) they lack demonstrated benefits, and (7) they lack specific standards. SECOVI-SP also released a note taking a position against federal PL 1703/2011, and Vanderley John, professor of Poli (Polytechnic School of USP) and adviser to the CBCS (Brazilian Council of Sustainable Construction), declared to the media: “Green roofing is like having pets at home - you need to like and take care of them. It’s a fantastic solution, but only when you have time to do proper maintenance”.

Facing so much criticism, a public hearing was called to discuss improvements to the Federal PL 1703/2011, resulting in the withdrawal of the mandatory term and opening the doors to fiscal, financial or credit incentives, as well as urban environmental compensation. This revision was influenced by ATVB, but still did not reflect a Brazilian green roof industry position or consensus.

So, in 2015 BASF decided to strengthen its position as the best cool roofing solution. With the white roof proposition stalled since 2011 at the Legislative Assembly of São Paulo and also in Rio de Janeiro, Espaço ECO foundation (a BASF initiative) released (on January 8th, 2015) a note entitled “Green roofing is not the most eco-efficient alternative for residential coverage”. Comparing three roofing alternatives (ceramic tiles, green roofs and reflective painting - cool roof) under a Lifecycle Evaluation model (ISO 14040), they concluded: “The Green Roof has a better economic and environmental performance compared to the Ceramic Roof, but it was not enough to be more eco-efficient than the cool roof (white painting).” Moreover, “the environmental impacts associated with green roofs in the categories of energy consumption, emissions, accidents and occupational diseases are determinant to impair their performance in relation to white roofing. The waterproofing blankets needed for green roofing come from petrochemicals, which lead to larger impacts”, they say. However, they never published the full report for peer review. At this point white roofing was already perceived as 'greenwashing' by Brazilian audiences. Worse, real green roofs and walls are perceived in much the same way.

The 11,330 square meter, green wall corridor along May 23rd Avenue in São Paulo is one that suffered from this perception. Built by Movimento 90º to be the largest green corridor in urban areas in the world, the 6 km of vertical gardens were installed in 2017 using resources from an 'Environmental Commitment Term', regulated by Decree 55.994, of the City of São Paulo, as an environmental compensation tool. This is probably the first time a local government used its power to redirect investments for green infrastructure in Brazil.

Signed by the São Paulo City Hall and a construction company that had cut about 800 adult native trees, the term proposed that instead of replanting 26,281 new trees in a degraded area according to the current law, the € 2,2 budget compensation (Zylberkan 2018) should be applied to build a 14,600 square meter green corridor in the central region of the state capital. Five of them were built on private buildings, but the new mayor changes the original project and the other three were built on a huge single public wall along May 23th Avenue.

However, arbitrarily, the new mayor decided to install the vertical gardens on top of one of the city's most famous graphite panels, vanishing the paintings forever and attracting the ire of several renowned artists, local civil society movements and environmentalists dissatisfied with the loss of budget for their projects, which began a campaign against the exchange of trees by artificial vegetated panels. The controversial financing mechanism eventually turned against the idea of promoting green infrastructure initiatives in the city and the project was publicized by news agencies as the 'greenwash scandal' (the project earned the pejorative nickname 'walled trees'), because, according to experts, instead of the 6 km extension of the green corridor, the compensation really should be 1,500 km long to be compatible with the 26,281 trees promised.

A little more than a year after its inauguration, the project was abandoned and, due to lack of maintenance and irrigation, started to demand high costs to reform and protect the equipment against vandalism. According to the press, the idea of vertical gardens lasted very little, and after the green corridor initiative, the city government revoked the decree that allowed the installation of green walls as environmental compensation for trees felled for building companies.

Soon thereafter, the city of São Paulo vetoed the article of Law 16.277 that made the installation of green roofs mandatory. According to City Hall, this type of installation cannot be made mandatory, as it would influence the construction of popular housing.

The fact is that, of the 12 Brazilian municipalities we found with approved green roof incentive laws, only two were put into practice. The first was the bad experience of São Paulo, using a Decree to redirect reforestation money and install the green wall corridors that I described above. More recently, Recife, Pernambuco, where it is mandatory for roofs over 400 square meters to be covered with green roofs. Sixty-five projects have been registered to date, but it is too early for us to make an evaluation yet.

A LITTLE MORE NOISE

Skygarden also caused more noise and confusion in the market, when they launched two campaigns: one to stop using plastic materials for green roofing; and another to suggest that the use of succulent plants was inappropriate. The first was based on the false premise that their green roof systems did not contain any plastics or other unsustainable resources, which is not a true, since they use geotextile sheets for drainage in all they combos. Moreover, the majority of plastic trays used for green roofing in Brazil are from recycled sources, contributing to their accountability in the long term.

The second campaign was almost xenophobic: in the attempt to promote native vegetation, Skygarden had published several articles and interviews saying basically that “in order to reduce costs, some companies use desert vegetation, which consumes little water but does not photosynthesize or contribute to the maintenance of diversity” (Jaggi 2018 b); and “(...) the use of succulent plants or sedum (species originating from foreign deserts) over Brazilian buildings. Nothing is more wrong for ecological sustainability, since these plants photosynthesize with little water release (type CAM) and provides scarce environmental services, they form true deserts in these areas” (Cardim 2010). Succulent plants from the genus Sedum where introduced long ago into Brazil. Although this genus has been used and studied for modern green roofs for years, the argumentation that they form ‘true deserts’ is fake news. Moreover, exotic succulent plants can play an important role as pioneer species for plant succession on green roofs in preparation for other biodiversity and native species promotion (Maggil et al. 2011).

GREEN ROOFING EDUCATION IN THE CLOUD

As you can see, we have a lot of work to do to educate Brazilians about green roofs. Workshops and courses on green roofing have become an increasingly common practice in Brazil, but sometimes more as a sale technique than an educational tool. All the companies involved in the sector give public lectures and we have many landscapers teaching this subject in their specialization courses. However, the scope of these initiatives is often superficial, and while green roofs are extremely attractive and well-known to the general public, the technique’s standards remain virtually unknown by technicians and by the academy. In fact, few people are aware that an industry exists and that there is an incipient movement to promote green roofs in the country.

Casa MM. Bragança Paulista, São Paulo (2011). Pitched Green Roof Project (810 square meter). Landscaper: Renata Tilli Paisagismo; Installer: Jardins Suspensos Jardinagem Vertical; Green Roof System: MODULAR Instituto Cidade Jardim.

Another education issue is the benefit/cost ratio. The effort invested in a face-to-face event is usually very large - time, travel costs, lodging, food, equipment rental and rooms. Most audiences have 20 to 30 students in a classroom for a limited period of time.

That's when we realized the potential of the internet to promote this market. In mid-2016, we decided to systematize our lecture contents and to record in video our first online course - 'Introduction to Green Roofs', and host it in an online teaching platform. Initially composed of three modules (preparation, materials selection, execution techniques), in 2018 we added a 4th module about marketing and renamed it the 'Green Roof Seed Program', adding on-site events for commercial and market discussions, demand mapping, sales management, customer service, etc. Teaching about FLL basics, local building regulations and our own field experience (from irrigation to commerce), with this initiative we intend to raise the overall technical level of the market, and form the next generation of green roof professionals and policy makers.

The numbers are expressive. In order to promote the course, we had created the 'Green Roof Week', a free online event where we presented several videos with basic content, as well as interviews with invited experts and professionals - all of this available online for the audience to watch and to share. This resulted in a nearly instantaneous increase in audience, prompting us to multiply our monthly audience by eight times in one leading social media platform, from less than 1,000 active users earlier this year to almost 8,000 monthly users following us by December 2018.

In order to identify and retain public interest in green roofing in Brazil, we held several digital media events throughout 2018. These included a series of seven professional videos about the benefits of green roofing (with a total of 2,712 views on Youtube), three editions of 'Green Roof Week', and several online technical classes (4 live webinars), transmitted exclusively in an internet environment. Between November and December 2018, we reached 238,166 people with our campaigns and a total of 810,092 people throughout the year - with an investment of € 3,700 in social media ads. As you can see, internet activism escalated green roofs to new audience level and can play an important role in education and popularization, with relatively low costs.

BIOMIMICRY FOR THE NEXT GENERATION OF GREEN ROOF PRODUCTS

Green roofs are expanding all over the world and already represent a significant market in Europe, which installed 11.3 million square meters in 2015 - well ahead of North Americans (about 300 thousand square meters yearly) and Brazil (about 100 thousand square meters yearly). Meanwhile these numbers represent about 0.1 percent of the global roofing market (which installed more than 11 billion square meters in 2018). This micro-percentage also demonstrates the huge potential for growth and impact that green roofs can deliver in the coming years.

One problem is that current green roof technologies are coatings for already waterproofed structures - usually a flat roof (most of the time a slab) with a waterproofing membrane. Thus, as well pointed by Porsche and Köhler (2003), roof gardening is not suitable for all kinds of buildings. In fact, 97 % of roofs in Brazil are not flat, being covered with clay or fiber-cement tiles, or metal sheets (CBCA & ABCEM 2014), hence not being able to be greened due structural restrictions and inherent adaptation costs. While we need to evolve as a movement to raise more governmental aid for market development, we also need to move toward more appropriate technologies.

With that in mind, we challenged ourselves to create a product that would not be an additional item in the building. The idea was to simplify the application of green roofs and, mainly, not to depend on a waterproofing membrane. To this end, we decided to seek inspiration in nature: by simulating the functioning of plant tissues in a leaf, we had the idea of creating the first hydroponic tile - a new single-ply hydroponic tile. This is a sandwich panel that does not require a slab or waterproof membrane, delivering greening and water tightness in the same product for the first time.

Instead of the traditional layering, the new system is installed as a conventional thermal sandwich panel, where overlapping and screws guarantee tightness and stability for (almost) flat roofs to a 90° inclination wall. Lighter than a regular clay tile, its dry weight is 10 kilograms per square meter. The saturated weight is about 45 kilograms per square meter, depending on plant selection. After assembling the panels over the roof structure, simply insert the drip irrigation lines and connect them to a water supply attached to a hydroponic system, so the internal irrigation circuit board will distribute the water without overloading the weight of the system. It is well suited for extensive green roof cultivation with species commonly used for landscaping, but its greater potential resides in intensive urban agriculture, allowing the cultivation of vegetables and grains. The tiles also possess excellent thermal and mechanical resistance, allowing people to walk on its surface for maintenance.

This new technology is protected by the Green Patents Program of INPI (Brazilian Institute of Intellectual Property) and, since 2016, its development has been supported by the program Smart Cities - Sustainable Cities of FAPESP (Foundation for Research Support of São Paulo) and FINEP (Funding for Innovation and Research, of the Brazilian Federal Government). Together, they brought investments on the order of €175,000 to prepare the product for the market, in exchange for a 20% stake in the product's patent.

The results obtained in this period were exciting and reinforced our belief in the market potential of the product. Our hydroponic tile presented positive results in all the cultivation tests carried out in Brazil, Italy and Germany, and was also approved in all the initial characterization tests carried out by IPT (Brazilian Institute of Technology, at São Paulo University), attesting that the product already complies with NBR 15.575-5:2013 (House Buildings: Performance - Part 5: Roofing Systems), or in other words: it does not leak, supports trampling for maintenance and is impact resistant. We also had positive advances in industrial development (validated mold design in industrial tests, selection of raw materials and good production practices, map of initial costs for price formation) and the commercial strengthening line (branding, visual identity, digital marketing campaigns, a new patent granted in Brazil and patents deposited in Europe and the USA).

We believe in the potential of this new technology. Our plan now is to introduce the new product to the market and to find local partners to develop it commercially in Europe and the US. This is our contribution to make green roofing suitable for a larger share of the overall roofing market.

RESULTS, CONCLUSIONS AND RECOMMENDATION

After a 10-year period we can say that an incipient green roof industry has been born and keeps hanging on in Brazil. However, for a business intended to attain scale and change the urban climate, the numbers need to be much better. We are talking about a 100 thousand square meter basis installed per year - a little bit more than 10 soccer fields. Although there is some inaccuracy in these numbers (we have only three green roof companies that published their results to date), green roofs have not yet taken off in Brazil. I identify main reasons:

One is the absence of an appropriate governmental climate. Although we have green roof incentive laws passed in 12 municipalities, we have the impression that we are moving in

Hydroponic Green Roof. Itu, São Paulo (2019). Beans growing into the new sandwich panel prototype - no waterproofing needed. Developer: Instituto Cidade Jardim.

the right direction. However, when we look more closely, we cannot say that any of these initiatives has resulted in more green roofs installed. Many of the texts of these laws are based on mandatory compliance, which has attracted hostility to these initiatives. In fact, the proposed federal bill was so criticized that the obligatory requirement was withdrawn and replaced by financial, fiscal or credit incentives. What we have repeatedly heard from politicians who advocate compulsion is that the state cannot give up revenue to invest in urban improvements, while demanding that the private sector invest. This kind of position has created tension, rather than agreement about how to proceed.

To understand the importance of government entering the game, the only project that was financed through an incentive decree represented almost the annual turnover of the three private companies that operated in that year. However, some of these laws are so confused that they lead to negative results for the public perception of the market, as is the case of the City of São Paulo, that took money from the reforestation of native trees to build a 6 km long green wall.

Another issue is the macro-economic scenario. After a period of good economic results, the Brazilian economy stopped growing in 2014 and a deep recession started in 2015 that lasted until 2017, with a timid expansion in 2018. This was combined with a long-lasting political crisis between 2016 and 2018. We don't have numbers from any other green roof company in Brazil, but in this period our sales dropped by 57%. The new Federal Administration has not taken a position on anything related to this market.

Another thing is the general ignorance of the population regarding these technologies, which is further aggravated when we have campaigns staining the reputation of the green roofs with white paint or when we see cases of vegetable xenophobia against exotic succulent plants. In this regard, I would like to comment on the points raised by the CBCS: (1) we do have systems adequate to the different Brazilian climatic regions, (2) we have an incipient supply chain that can deliver green roofs in any city in the country with more than 100 thousand inhabitants, (3) in order to avoid poorly installed green roofs we must advance in standardization, (4) in order to overcome inaccessible costs we must evolve financial tools in the same way photovoltaics did, (5) extensive green roofs have very low maintenance costs, (6) modern green roofs have a wide bibliography of demonstrated benefits.

What brought us here will not take us to the next level, so, in order to open up the benefits of green roofing to a wider audience and change our cities' climates, we must bring more new entrepreneurs, professionals and civil society actors to advocate for it. Permaculture brought inspiration to a whole generation of professionals, but the connection to a more technical and standardized movement, such as the green roof movement (which connects straight to the building industry), can leverage our cities to the next level.

Although today there is a broader commercial acceptance of green roofs in the building market (especially within leading building contractors, big corporations and signature houses), it's clear that there is latent demand in the middle class - and here governments can play a game-changing role to make it happen, through different financial aid and tax reduction incentives, as in the rest of the world (Magill 2011).

Despite the bad business and political environment in the last years, green roofs came to stay and they configure one of the most successful cases of green building techniques being spread across the country. They are being adopted in both favelas and signature houses. Leveraging Brazilian green-roof markets and moving from one hundred thousand to one million square meters installed per year is not an easy task, and will be our goal for the next years.

REFERENCES OF THE CHAPTER AND RECOMMENDED READINGS

CBCA & ABCEM (2014): "Perfil dos Fabricantes de Telhas de Aço e Steel Deck -Executive Research Report". CBCA (Centro Brasileiro da Construção em Aço) & ABCEM (Associação Brasileira de Construção Metálica). O Nome da Rosa Editora.

EFB (2015): "White Paper". EFG (European Federation of Green Roofs & Walls). EFB.

Cardim, R.H. (2010): "O Telhado Verde e a Escolha da Vegetação – Plantas Suculentas (Sedum) X Vegetação Nativa". Árvores de São Paulo: Verde urbano, árvores e resgate da biodiversidade nativa na metrópole. https://arvoresdesaopaulo.wordpress.com/2010/02/09/o-telhado-verde-e-a-escolha-da-vegetacao/

Jaggi, M. (2018 a): "Prática se destaca entre soluções sustentáveis". Jornal Valor Econômico. Macroeconomia. 15/Mar/2018.

Jaggi, M. (2018 b): "Telhados de edifícios ajudam a resgatar plantas nativas". Jornal Valor Econômico. Macroeconomia. 15/Mar/2018.

van Lengen, J. (1997): Manual do Arquiteto Descalço. Livraria do Arquiteto. Rio de Janeiro.

Magill, J.D., Midden, K., Groninger, J., Therrell, M. (2011): "A History and Definition of Green Roof Technology with Recommendations for Future Research" (2011). Southern Illinois University Carbondale Research Papers. Paper 91. http://opensiuc.lib.siu.edu/gs_rp/91

Mollison, B. (1988): Permaculture: A designers' manual. Tagari Publications. Australia.

Porsche, U. & Köhler, M., (2004): "Life Cycle Costs of Green Roofs - A Comparison of Germany, USA, and Brazil". Proceedings RIO 3 - World Climate & Energy Event. 1-5 December 2003, Rio de Janeiro, Brazil. pg. 461-467. http://www.rio12.com/rio3/proceedings/RIO3_461_U_Porsche.pdf

Zylberkan, M. (2018): "Prefeitura não paga conta de água e luz, e muro verde de Doria definha na 23 de Maio". Folha de São Paulo. Cotidiano. 22/Oct/2018.

mercado de S Sebastião
A MINHA SÉ É LINDA

San Sebastiao
Market. Oporto.
I. de Felipe

CHAPTER 16

GREEN ROOFS IN PORTUGAL: FROM INVISIBILITY TO THE DEVELOPMENT OF AN INCENTIVE POLICY FOR THE CITY OF PORTO

Beatriz Castiglione and Paulo Palha
Portuguese Association for Green Roofs (ANCV)

More than a hundred years ago, in the city of Porto, one of the first Portuguese green roofs (GR) was built in an ancient water reservoir located in the space known today as "Parque da Pasteleira". This green roof, constructed in the XIX century, was built with the traditional green roof system and corresponds today to one of the great testimonies of this construction technic in Portugal. Similar to this project, perhaps the oldest in Portugal, Porto and Lisbon host numerous cases of GR, many of them invisible to the general population (since most of them are on street level), who still consider it a recent practice in the country. This green heritage, however, has gradually received more attention and is moving towards greater recognition in the era of Nature-Based Solutions for cities, even though the way to get here has not been easy.

BRIEF EVOLUTION OF GREEN ROOFS IN PORTUGAL FROM THE 1960'S TO 2000

Although there may exist other examples of historical GR from the XIX century, it was only in the middle of the XX century that they started to be popular in Portugal. One of the first buildings in the country to receive a GR was the Garbe Hotel, in the region of Algarve, followed by the Ritz Hotel in Lisbon. The experience acquired by the landscape architect Viana Barreto in the last one was essential in the development of the first big emblematic GR project in Portugal: the Calouste Goulbenkian gardens green roofs, designed by Viana Barreto and Gonçalo Ribeiro Telles around the 1960s (Dias, 2014). This garden is one of the most important gardens of the modern movement in Portugal and a big reference for the Portuguese landscape architecture.

During the 1960's, Portugal was going through the longest-running dictatorship in Europe, all while raging wars against its colonial territories in Africa, culminating in the Portuguese revolution of 1974. Because of that, in this period there was a gap on the construction of GR.

Almost a decade later, in the 1980s, other important GR projects were launched, such as the one from the Portugal Telecom building and the "Centro Cultural de Belém", built in 1989. The green roofs market kept growing shyly in the private sector during the 1990's and experienced a boom after the famous world exposition EXPO 98. This world exposition, which took place during the summer of 1998, was a booster of construction; specially promoting the sustainable solutions that presented energetically efficient technics (Magalhães, 2001). In "Parque das Nações", the new urbanized area of Lisbon, it is possible to find many residential and commercial buildings with GR from this period.

The first decade of the years 2000 was very important for the development of new and modern GR projects, some of them from very reputable names of Portuguese architecture, such as Carrilho da Graça, Álvaro Siza and Souto Moura, who used GR in one of his most important works: the Braga stadium (Cannatá, 2007). During this decade GR evolved from the private sector and had more visibility to the general population, as more projects in the public spaces started to appear. Examples are the Trindade station and the Lisbon Square, both in Porto. The Lisbon Square GR, built in the historical centre of the city, gave back to the citizens a space that has been abandoned for years and corresponds today to one of the most successful public spaces and great postcards of Porto (https://architizer.com/projects/praca-de-lisboa/)

Gulbenkian gardens GR (source: Portuguese Association for Green Roofs)

Gulbenkian gardens GR (source: Portuguese Association for Green Roofs)

Although GRs became more popular during the second decade of the years 2000, they remained relatively unknown and with their potential underestimated in Portugal, leading to some unacceptability and misinformation among some group of professionals, politicians and the population in general. In parallel, following the global trend, Portuguese cities are becoming more populated over the years. This tendency requires different ways of planning, governing and building cities, which demands the planners to find new and different technics to work the city as an ecosystem. Within this context, with the objective to promote GRs in the cities, a group of professionals committed to the cause created in 2015 the Portuguese Association for Green Roofs (ANCV).

THE PORTUGUESE ASSOCIATION FOR GREEN ROOFS AND THE FIFTH FAÇADE PROJECT

The objective of ANCV is to promote green infrastructure in cities, especially those that can be installed on buildings (new or pre-existing) such as GRs, highlighting their enormous importance, and the numerous contributions they can give to the possibility to create healthy, sustainable, biodiverse and resilient urban territories. To do that the association establishes a triangle of connections between research institutions, municipalities and companies that are linked to the international community, since the association is a member of the World Green Infrastructure Network (WGIN) and the European Federation for Green Roofs (EFB).

With the work of the association and the growing popularity of the technology all over the world, GRs market has been growing in Portugal over the last years. Nevertheless, the dissemination of GRs, initially in Europe and later in the world, was only possible due to the numerous incentive policies that promoted their construction, based on research about its environmental, economic and social benefits. Without political will, it is difficult for GRs to

Centro Cultura de Belém (source: Portuguese Association for Green Roofs)

be implemented on a large scale in cities, and without a large-scale implementation in the city the benefits of GR are not significant for the urban environment as a whole.

Aware of this reality, and following his long term conviction that "vegetation should become a mandatory building material", Paulo Palha, the President of ANCV, wrote and proposed to the Porto municipality the Fifth Façade Project (PQAP), a project whose purpose was to define which models the municipality of Porto should follow in order to include green infrastructure, in particular GRs, into the urban planning, environmental and climate change strategy of the city. The municipality enthusiastically received the project, and the cooperation between ANCV and the city council started in August 2016.

The work of PQAP was developed in collaboration with research groups from different Portuguese universities, as well as with councils of two foreign cities with more experience in GRs policies: London and Linz, chosen by the PQAP team with the help of the WGIN and EFB federations.

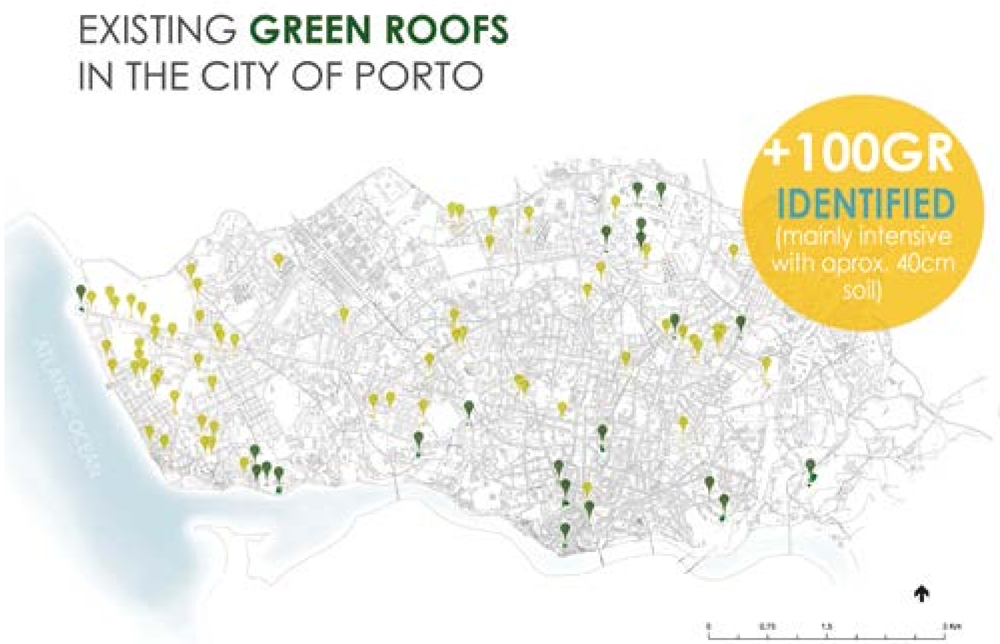
The methodology included the choice of two municipal buildings to receive green roof projects, the realization of the inventory of existing green roofs in the city, mapping the potential of existing buildings to receive a green roof in the city and launching the first Portuguese guide for project, construction and maintenance of GRs.

Besides, one of the most important parts of the project was related to the attention given to the performance of the roof in the development of the policy proposal. If for many years the focus in Europe was on creating incentive policies without necessarily distinguishing the type of green roofs they were promoting, now the lens should be on what kind of green roofs we want in cities, according to the services they can offer and the different environmental needs for each city. Therefore, policies should never ignore the characteristics of the green roof, requiring and promoting certain aspects that present advantageous benefits for the cities, which may obviously change from case to case, since both practitioners and researchers must know how to apply the politics into their own reality.

Lisbon Square Porto. Portugal

Trindade metro station, in Porto (source: Portuguese Association for Green Roofs)

PQAP team on field to choose a model municipal building to receive a GR project (source: Portuguese Association for Green Roofs)



Map of existing GR in the city of Porto (source: Portuguese Association for Green Roofs)

The Fifth Façade Project developed by the PQAP team was delivered in August 2017 and is currently under evaluation by the different sectors of the municipality, in order to decide if it will become a policy and in which ways.

The adoption of a policy for GR in Porto will represent a big step in the history of GRs in Portugal. If green roofs have been important for the construction sector for many years, now it is time to give a step forward and become a strategic piece in a bigger urban plan, associating it with other nature based solutions necessary for the proper functioning of the urban environment.

Finally, whatever the decision of the municipality may be, the impacts of the project in the city are already visible, for example with the new project of the Campanhã bus terminal, approximately 2-hectare park with 13000 m^2 of green roofs. The competition for the project, launched by the CMPorto, required the presence of GR.

The pressure for a policy that considers GR in the strategy of a city is more and more strong and supported in Portugal. Hopefully it will not take long for Porto to become the first Portuguese city to have a GR policy and push the same attitude across the other municipalities of Portugal.

We feel that GR are no more an issue for some “special” people with environmental concerns, but it is a trend in new developments, a concern of municipalities and an issue for different research groups In Portugal, and an industry that is growing.

REFERENCES

Cannatá, M. Fernandes, F. (2007). Estádio Municipal de Braga de Eduardo Souto de Moura.

Dias, L. (2014). Reabilitação do edifício da Escola Ambiental da Quinta da Gruta através da implementação de uma cobertura ajardinada. Faculdade de Ciências da Universidade do Porto.

Magalhães, M.R. (2001). A Arquitetura paisagista em Portugal. Morfologia e complexidade. Editorial Estampa

(https://architizer.com/projects/praca-de-lisboa/

CHAPTER 17

ENGLAND: GREEN ROOFS IN LONDON FROM POLICY TO DELIVERY

Dusty Gedge
Director Livingroofs.org,
President European Federation of Green Roof Associations

Ben Moat
Msc Architecture: Advanced Environmental Energy Systems.
Centre for Alternative Technology, Wales

INTRODUCTION

In March 2008 the new London Plan, published by the Greater London Authority, was launched. This strategic document is a statutory requirement for the London Government (see endnote for brief overview London Government and the London Boroughs) The new London Plan announced a major a shift in policy in terms of green roofs and green walls. The previous London Plan, published in 2004, had merely 'encouraged' the use of green roofs and walls in new developments. The new version included a distinct policy. The policy had transformed form 'encouragement' to 'expectation', the first robust policy in the United Kingdom. Since then the policy, along with actions at prior to 2008 have seen the uptake of green roof in London grow exponentially regardless of the financial crash in the late 2000s.

BEGINNINGS

In the late 1990's the UK government's drive to build on post-industrial land lead to a surprising champion of green roofs. The Black Redstart (*Phoenicurus Ochruros*), protected under law, is a rare breeding bird in the UK. This bird is generally found on post-industrial wastelands, known as brownfields, in cities such as London and Birmingham. These habitats, whilst not pristine wildernesses, nurture the majority of the UK's breeding population. In response to the threats faced by breeding Redstart pairs from encroaching development the London Wildlife Trust and the London Biodiversity Partnership identified the need to replace lost habitat at roof level. Therefore the notion of the 'brown' roof emerged to essentially create a brownfield habitat at roof level (2).

The publication of the Urban White Paper in 2000 outlined the strategic view that development should be focused on Brownfield sites rather than Greenfield sites. However research and evaluation of these sites by ecologists soon demonstrated that many of these plots of land were of great importance for a whole range of rare species of invertebrates that had become extinct in the wider countryside (8).

The growing interest in how green roofs could benefit biodiversity and how their implementation in new developments could be used to both mitigate and compensate for the loss of ecological value at ground level led to one of the first major reports on green roofs in the UK by the English Nature (now Natural England). Not only did this report advocate the use of green roofs for biodiversity but also effectively highlighted their benefits across the broader sustainability agenda (3).

On a practical level a number of organizations such as the London Wildlife Trust, The London Biodiversity Partnership and the Environment Agency were actively pressurizing developers to install green roofs for ecological mitigation and compensation purposes. Most of these projects in the early 2000s were focused along the River Thames in the centre of London, where many new residential apartments blocks were being built.

CLIMATE CHANGE – A SHIFT IN EMPHASIS

During the mid 2000s there was a distinct policy shift as the climate change agenda gathered momentum. A series of excessively hot summers resulted in the London mayoral agenda, from having previously been concerned with issues surrounding 'fuel' poverty, widening it's emphasis to incorporate concerns regarding 'cool' poverty and the likely impacts of increased summer temperatures and negative effects of the Urban Heat Island. The London Climate Change Partnership stated in 2002 that *'Summers by 2050 will be 1.5 – 3.50C hotter…in central London the urban heat island currently adds 5 -60C to summer night time temperatures and will intensify in the future' (6).*

Thus green roofs were recognised to be a potentially multifaceted solution that could assist the capital meet the challenges of climate change and help adapt to the likelihood of higher summer temperatures and increases in intense summer storms (leading to localized flash floods). These fears have been realized to a certain extent with the exceptionally hot summers of 2005 and 2006 and extensive flash flooding of 2007.

London has both a central strategic authority (Greater London Authority) and also 32 local boroughs (LB) with responsibility for their area. A number of these boroughs, notably Islington, Lewisham and Tower Hamlets, were actively promoting and ensuring that green roofs were installed for nature conservation.

THE NEW LONDON PLAN

In 2007 the author, along with colleagues, was commissioned to write a technical review of green roofs and green walls. This report was to support the change in policy on green roofs from one of 'encouragement' to expectation'. The report reviewed all the technical data available for a range of benefits including reduction in the urban heat island, thermal performance, storm water attenuation, biodiversity and amenity. It also reviewed city policies elsewhere in the world. The technical report, published in late 2007, lead to a distinct policy on Living roofs and walls in the revised London Plan published in March 2008.

The new London Plan Living roofs and wall (Policy statement 4a 11) states:

The Mayor will and the boroughs should expect all major developments to in corporate living roofs and walls, where feasible and reflect this in Local Development Framework policies.

Interior garden. Tokio. I. de Felipe

It is expected that this will include roof and wall planting that delivers as many of these objectives as possible:

– Accessible roof space

– Adapting and mitigating for climate change

– Sustainable urban drainage

– Enhancing biodiversity

– Improved appearance

Boroughs should also encourage the use of living roofs in smaller developments and extensions where the opportunity arises [5]

Although it is too early to evaluate the effectiveness of the new policy, green roofs have been delivered on an increasing scale in the capital over the last 8 years and the new Plan should continue to enhance this momentum.

AUDITING LONDON'S GREEN ROOFS

Livingroofs.org undertook an audit of green roofs in London in 2004. The total area of green roofs was underestimated due to the challenges of accessing extensive and detailed information from architects, developers and companies. The audit estimated that 96,682m^2 of green roofs had been installed in the Greater London area. Some of these roofs dated back to 1932!

However in 2014 an audit of all the existing green roofs in Central London was undertaken. This was commissioned by the GLA and was undertaken by the author. The total area of green roofs in central London currently stands at 179,000m^2 – this just under twice the original audit for the whole of London. Since then two further unpublished as yet audits have been undertaken for two of the London Boroughs. The London Borough of Tower Hamlets has over 170,000m^2 of existing green roofs. This is not surprising considering it is an area of London where a great deal of new development has occurred over the last ten years. Across the river an audit of the London Borough of Lewisham shows that there are 60,000m^2. It must be noted that this borough is relatively suburban and conventional pitch roof dwellings take up the majority of the land area. Furthermore this district was one of the first boroughs to push green roofs through planning back in the early 2000s. It is also interesting to note that at least a fifth of the roofs are combined solar and green roofs – redently referred to as biosolarroofs.

Taking these figures an estimation of the current green roof coverage of London can be made. Excluding the City of London and Westminster, which area covered by the figure from for Central London there are a further 31 boroughs. Using the lower total for the London Borough of Lewisham then the total estimated area outside Central London could be 1.8 million m^2. Therefore the total estimate area for London equates to just less than 2 million m^2 (21 million ft2). This shows the growth of the green roof market in London has had a significant impact in London over the last 15 years.

GREENING EXISTING BUILDING STOCK

The potential for greening the existing building stock in London was highlighted int eh original technical report to support the new London Plan. A series of 1 km sections of central London were reviewed to understand how many existing roofs could potentially be retrofitted with green roofs. The estimate was that 32% of the land area of Central London had the potential to be greened. A series of green infrastructure reports in recent years has qualified this area. In the Victoria Business Improvement District (BID) the total potential area was around 29% and in several other audits of BIDSin London the figure varied between 25% and 33%. Taking an average of 28% the potential for greening existing stock in London is immense.

Cristal Tower. Madrid. I. de Felipe

A note should be made on how the above calculations are arrived at. A good proportion of flat roofs in Central London are inverted roofs covered in shingle or pavers. Removal of this element would allow a reasonably good green roof to be installed. There are quite a few examples of where green roofs have been retrofitted on inverted roofs in Central London and elsewhere in the capital, so although some commentators maybe sceptical of the potential the figures do add up.

The importance of retrofitting green roofs needs to be highlighted, especially in the light of the new EU Green Infrastrucure and Ecosystem Services Policy. Whilst planning can deliver green roofs on new developments, cities like London will need to consider how they can adapt the existing building. To ensure the urban fabric is resilient to climate change existing buildings will be key. Cities are mainly made up of buildings, and therefore green roofs will have to play an important role in helping the existing fabric of the city adapt.

CONCLUSION

Over the last 15 years London has taken great strides in delivering green roofs. From near total resistance from the mainstream-building professionals back in the late 1990s green roofs now an important and accepted building technology. Through championing and development of policy and guidance, green roofs are not only being installed they also being delivering to meet specific policy agendas within the capital.

Although London may not appear to many to be one of the leading green roof cities in the world, the figures outlined in this chapter show otherwise. As the agenda moves toward the retrofitting of green infrastructure into the existing urban core, London through its existing auditing processes is when placed to lead the way.

REFERENCES

1 *City of London (2003) Green Roofs Research Advice Note [www.cityoflondon.gov.uk]*

2 *Frith, M. & Gedge, D. (2000). The black redstart in urban Britain: a conservation conundrum? British Wildlife, 8, 381–388*

3 *Grant, G., Engleback, L. & Nicholson, B. (2003). Green roofs: Their potential for conserving biodiversity in urban areas. English Nature Research Report 498. Peterborough, U.K. English Nature*

4 *Green roof toolkit - http://www.environment-agency.gov.uk/regions/thames/323147/2093788/?version=1&lang=_e*

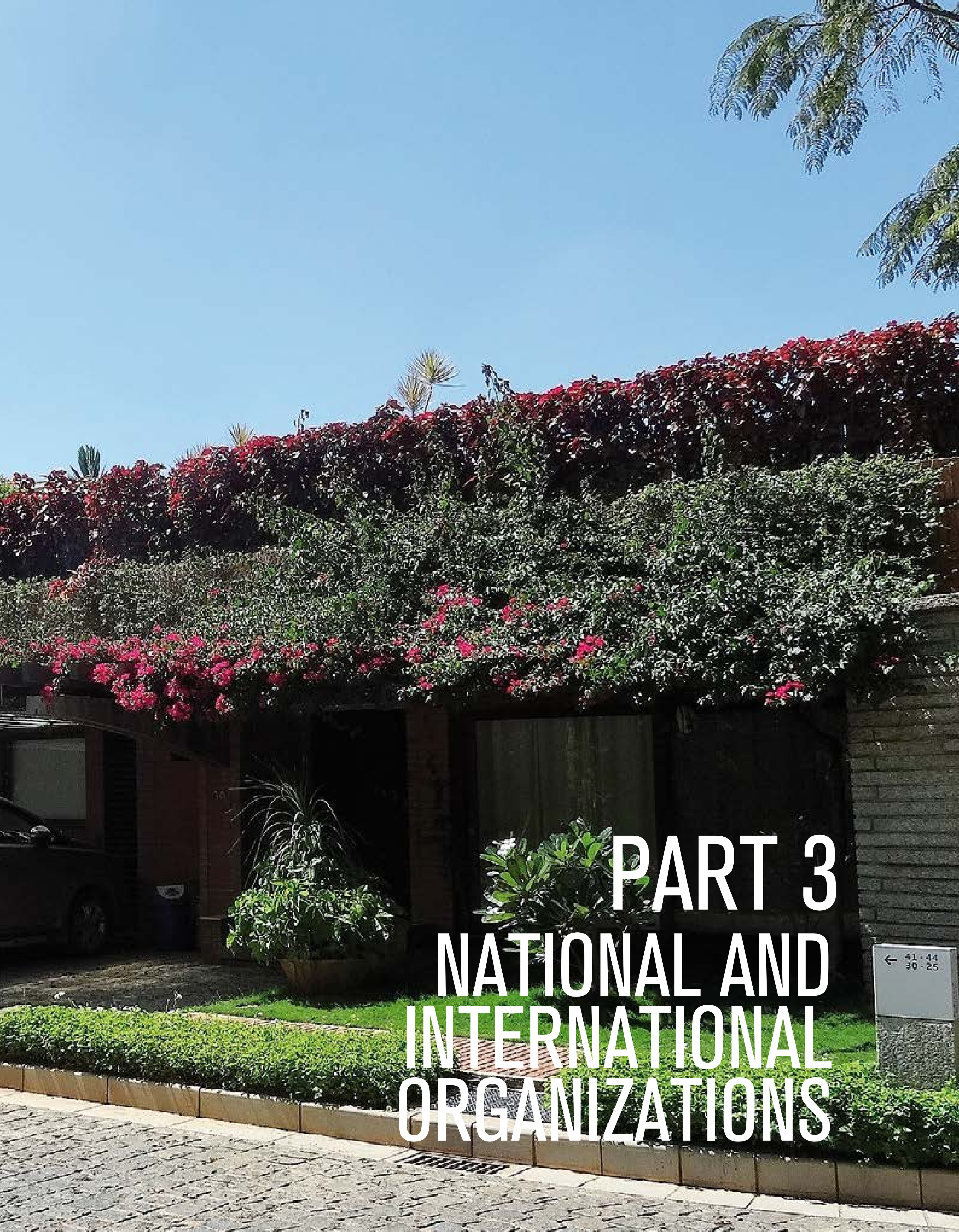
5 *Living roofs and walls – technical report to support the London Plan 2007 http://www.london.gov.uk/mayor/strategies/sds/tech_rpts.jsp*

6 *London's warming: The impacts of climate change on London http://www.london.gov.uk/lccp/publications/impacts.jsp*

7. *http://www.manchester.ac.uk/aboutus/news/archive/list/item/?id=2780&year=2007&month=05*

8 *Our Towns and Cities: The Future - Delivering an Urban Renaissance (The Urban White Paper) 2000 http://www.communities.gov.uk/archived/general-content/citiesandregions/publicationscities/urbanwhitepaper/*

Green roof parking.
Bangalore. India.
I. de Fellipe



PART 3
NATIONAL AND INTERNATIONAL ORGANIZATIONS

Toronto green terrace.
I. de Felipe.

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
Secretary: Tanya Excell
Treasurer: Zoe Zimmerman
Board: Kirsty Ruddock; Rosie Mohorko; Robert Griffith

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 Institution 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

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, and 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.
In 2014 GRA held the 2014 World Green Infrastucture Congress in Sydney with 32 International and National leading authorities in the discipline of green infrastructure research; design; technology and installation. The 2014WGIC was attended by 420 delegates."

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/
- 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.

Source: Matt Dillon.

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

AUSTRIA

Organisation:
Verband für Bauwerksbegrünung, VfB
Wiedner Hauptstr. 63, Postbox 351
AT-1045 Vienna, Austria
Type of Organisation: Non-Profit Organisation
Contact Person: Vera ENZI (Spokeswoman), Gerold STEINBAUER (President), Elisabeth GRUCH-MANN (Secretary)
Email: office@gruensattgrau.at
Website VfB: www.gruenstattgrau.org
Website GSG: www.gruenstattgrau.at
Phone: +43 650 634 96 31

ABOUT US

The non-profit Austrian Green Roof and Living Wall Association (VfB) was founded in 1991 and brings together over 70 industry and business players, planning, delivering and maintaining greened buildings in Austria. Since 2017, the Austrian association (VfB) is 100% owner of the Austrian competence centre and central coordination unit GRÜNSTATTGRAU, the Innovation Laboratory for Green Cities. GRÜNSTATTGRAU is supported by the Austrian Ministry of Transport, Innovation and Technology and consists of a partner network of over 300 entities from public, research and business sector. GRÜNSTATTGRAU is facilitated by three different experts panels formed by the network partners (business, scientific and external advisory board) who are supervising GRÜNSTATTGRAU with their expertise.

MISSION AND CURRENT STATUS

In light of its background of the Austrian Green Roof and Green Wall Association, GRÜNSTATTGRAU is focussing on the future of urban green environment, innovations and ideas for green cities, products and services, activities targeting research dissemination and knowledge transfer, technical implementation guidance, co-creation activities and economic and social cooperation regarding Green Infrastructure and nature based solutions on buildings and their implementation.

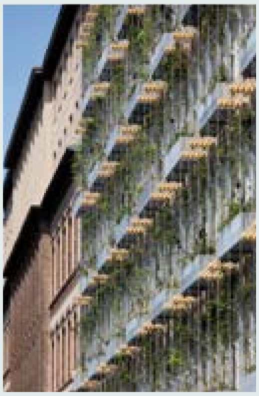
The aim is to promote all levels of green on buildings through communication, demonstration projects, business incubators, law and policies activities – not only on national, but also on European level. The intention is to upscale and share the results with all partners in the European network and market (knowledge transfer). The trade of the greening industry is now highly demanded and ready for rollout. After publishing the national standards for green roofs ÖNORM L1131 (2010) and interior landscaping ÖNORM L 1133 (2017), a committee of experts (VfB) are currently working on the Austrian Standards of outdoor vertical greening (ÖNORM L1136), including the results of the latest fire protection tests. Furthermore, GRÜNSTATTGRAU is supporting cities to set up strategies including green infrastructure. The demand of action taking within cities for climate change adaption is rising.

The instruments of GRÜNSTATTGRAU are including demonstration testbeds in different cities, a moving Green Laboratory on roadshow and a multi-stakeholder online platform to develop and offer own supporting tools, services and technologies.

The mobile Living Lab unit test-track roadshow of GRÜNSTATTGRAU is a reconstructed cargo container called MUGLI that is used to demonstrate various kinds of green roof, outdoor and indoor green wall technologies, energy production, pollinator and bird supporting technologies and in general new innovative approaches for green

The mobil Living Lab, named MUGLI in Vienna

Residential Green Roof, Sargfabrik Vienna



Greening the facade with climbing plants, municipality building MA31, Vienna ©Rataplan.

Austrians largest sustainable, self-seeding Green Wall, municipality building MA48, Vienna

Urban Gardening Residential Green roof, OASE 22, Vienna

and energy infrastructure. MUGLI stands for mobile.urban.green.living.innovative. It is used for information and communication work, awareness rising, events, as an experimental space, to generate live monitoring data and as a meeting point and physical centre to show green technologies come alive. Since summer 2017 MUGLI is touring through Austria and beyond to bring the greening technology to all target and synergy partner cities of GRÜNSTATTGRAU.

The GRÜNSTATTGRAU online platform (www.gruenstattgrau.at) is a multi-stakeholder platform for all network partners of GRÜNSTATTGRAU and the interested public. It provides information for green cities and nature based solutions, greening technologies and best practice of green buildings. The online platform includes databases for showcase projects, products, R&D-projects and greening experts and provides different online services of GRÜNSTATTGRAU, for example a free digital first level consultancy service for projects called "Greening Check". Event calendar and newsletter are implemented. In the internal area we provide studies and data for premium users. All network partners of GRÜNSTATTGRAU have online profiles to present their innovations, products, projects or ideas online.

The Green Living Laboratory GRÜNSTATTGRAU represents an innovative approach for facilitation and multiplication of national, European and global interests in Climate Change adaptation through Green Infrastructure and Nature Based Solutions.

BELGIUM

Adress: Grote Moerstraat 76, 8200 Bruges (Belgium)
Mail: simon@greenbuildingprojects.be
www.gevelendakgroenfederatie.be

Recreation Center.

CURRENT PRESIDENT

Simon Perneel

SIZE OF THE ASSOCIATION

20 membres

Founded in 2018, the federation reunites around 70% of of contractors of green roof and green walls in Belgium. The federation is lead by a board meeting every two months and guided by a member comittee every four months.

The mission is to improve the quality and the public awareness of green roofs and green walls in the construction market. To achieve this, several specialized comittees focus on determine qualifications of the different layers and the relation between. For that, it's focussing on existing European quality requirements, current scientific knowledge and external imput of experts. It's aiming to develop general standard requirements by the end of 2019 in order to dessiminated these requirements to architects and other stakeholders.

Parallel to this, first steps are taken to organise a quality label and the assessment systems of it in order to encourage contractors and architects to aspire for qualitive green roofs and green walls. Current and future research projects are supported in order to close knowledge gaps of regional-related topics and in European programs.

Regional projects on the promotion of green roofs (and wider aims as biodiversity) are supported.

The federation acts also as an intermediate organ between the members and the governement for topics as the drought of 2019.

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.

BRAZIL

Sérgio Rocha Founder | Instituto Cidade Jardim
sergio.rocha@institutocidadejardim.com.br
+55 11 98322-1728
www.institutocidadejardim.com.br

HISTORY

Instituto Cidade Jardim (The Garden City Institute) is a Brazilian company founded in 2008 to offer regenerative solutions to heal the urban environment, using the rooftop market to achieve the scale of transformation we must reach to cope with urban development challenges for the 21th century.

We design and produce materials for green roofs, having installed over 80,000m2 in these first 10 years. We also offer online courses and training for students from all over the world.

In 2012 we patented a brand new green roof solution to bring all the well-known benefits of green roofing to those buildings (and also houses, sheds, etc.) without slabs or waterproofing membranes, with the PLUS capability to work in a closed hydroponic loop, fed with reused water - it's water conservative, turns dirt water into biomass or food, and promises to make green roofs more accessible to the developing world.

In 2016 we were granted by the Sustainable Cities - Intelligent Cities award offered by FAPESP and FINEP (Brazilian development agencies) to improve product research and to make this innovation ready for the market.

MISSION

To make current dry roof technology so obsolete to the point that, in the near future, instead a desert, we will look at the city skyline and see a forest canopy.

OBJECTIVES

We intend to do for the green roof industry the same Steve Jobs made for the personal computers. Along with our new patented all-in-one green roof technology, green roofing will be easier and finally at reach for all those who has a roof. The new product launching is planned for the 1st semester, in Brazil.

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.

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

Roof gardens in the style of a Chinese garden in Hangzhou. Source: M. Köhler

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 m^2 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/

COLOMBIA

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 m2 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:

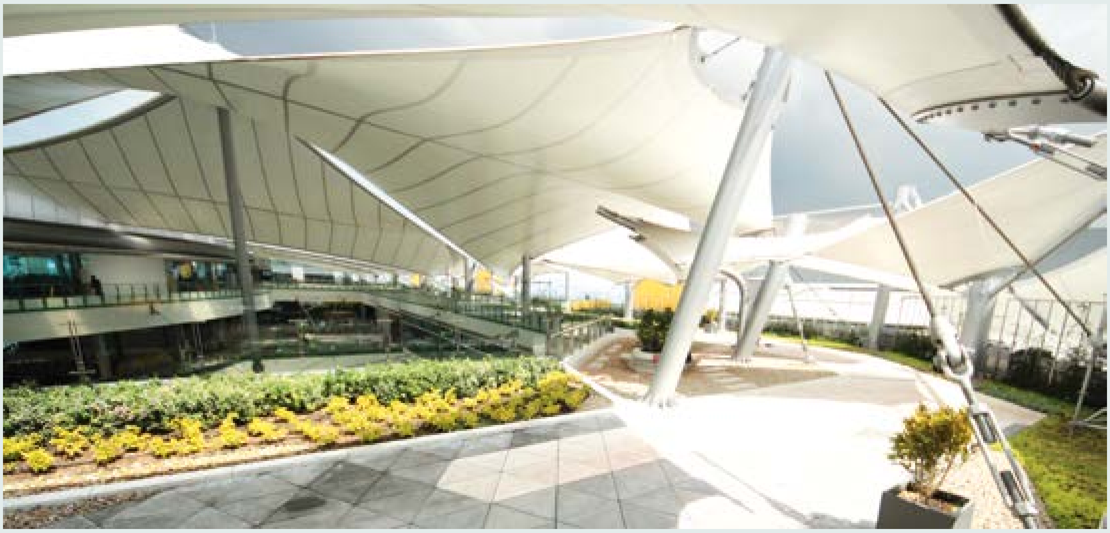
- Chair: Andrés Ibáñez G.
- Vice-chair: David Perico
- Treasurer: Pablo Atuesta
- Secretary: Luis Alberto Suarez

CONTACT PERSONS:

Andrés Ibáñez G.
raibanez@hotmail.com

HOMEPAGE:

www.recive.org



Source: A. Ibañez

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

CUBA

National organization:
Calle Amargura 60, lower level,
between Mercaderes & San Ignacio
La Habana Vieja, Cuba
C.P. 10100
Email: ana@scivil.ohc.cu
Website: www.sociedadpcma.org.cu
Telephone: (537) 8649512 y 13

HAVANA: TWO INITIATIVES FOR THE HUMAN'S WELFARE AND ENVIRONMENT

Located in the area inside of the walls of the old village San Cristobal de la Habana, in the capital city, its historical center has gone through a large process of transformation thanks to the work of a multitask team, led by Havana's city historians office. Declared in 1978 national monument and in 1982 world cultural heritage by UNESCO, in 1993 was one of the priorities among the areas aimed to conservation (ZPC)1 , and in 1995 among the most important areas aimed for tourism. The model for urban recovery that it promotes, tries to reach an alive- Historical Center, linked to the life quality of its citizens. That's why the different work fields meet the same challenge of influencing on the human being's welfare and keeping the environment's quality.

Because of the reduced amount of spaces, in the Historical Center the green areas are located mainly in the Port Avenue, Prado, Central Park and Fraternity Park, which comprise 18 hectares of total surface. In its interior, the restoration works in the oldest part of the city has paid special attention to parks and squares. It is frequently seen the use of flower boxes in balconies and inner gardens in the old houses and buildings. Achieving good harmonization in this process through the use of empty spaces where old buildings collapsed is one of the objectives; they have turned into parks with urban furniture with a lot of green and sport fields. Such a practice has had good acceptance by the inhabitants besides of contributing with the improvement of the environmental situation and image of the local area. Simon Bolivar, Las Carolinas, and Carlos J. Finlay Parks are great examples. The new environmental strategy of ZPC 2013-2020, has as objective to reinforce the work projections towards green areas and biodiversity, with programs aimed to rehabilitate and create new green spaces and to improve its management. Little by little appear small family gardens in inner yards and roofs. The strategy emphasizes on promoting the inclusion of environmental dimension from the projects' conception and design, all of it according to the good use of natural and urban resources, the implementation of better practices like cleaner production and sustainable consumption, the insertion of green spaces and climate change adaption.

La Quinta de los Molinos, located in Havana's heart, has recently been assigned to the Historian's Office so that it would be rescued as well as its heritage, environmental and historic values. It borders Cerro, Plaza and Centro Habana. Declared in 1981 National Monument and previously Botanical Garden of Havana and Cuba, started to work as a facility of environmental education on September 2011.Since then, many didactics workshops and tours have been developed in different specialties, in order to teach the students how to take care of the environment and use the natural resources in a responsible way.

Nowadays, the Quinta de los Molinos has 4.8

hectares, creating the first wooden band in the city, it has almost 170 species of plants, 14 of them are originally from Cuba, the most common are the arborous ones, followed by the herbaceous one and finally, in a less degree the shrubs one. According to the size of this land, the location in the city, and the diversity in the flora, we can find a wild fauna associated with the vegetation of this place. In 2005, specialists from the Instituto de Ecología y Sistemática, of the Ministerio de Ciencia, Tecnología y Medio Ambiente (CITMA) made a research and they found 66 species, 19 of them were mollusk (7 fluvials and 12 land ones) including 1 endemic of this área, 2 amphibious, 8 reptiles, 32 birds (14 migratory) and 5 species of mammals. In 2010, students from the Faculty of Biology of the Havana's University made a research in order to characterize the invertebrates in the area, reporting a large number of individuals from different species.

Among the first programs of the Quinta de los Molinos, we can find the social work, with activities like gardening, organic productions, permaculture, animal well-being, among others. Also, it offers veterinary consultation and to worm pets. Also it gives special attention to senior people, so they can find here an excellent place to talk about topics related to natural science, environment, international culture and protection of nature.

The environmental educational labor of this institution combines the theory given in the classrooms with the practice in natural areas. Students from the primary and the secondary level schools are the ones that take more advantages of this place. This Garden also supports an important subject called «El Mundo en que Vivimos», this subject is taught to the students that are in 4th grade. They also receive guided tours in this place. Besides, it contributes in the practical formation of

Las Carolinas

Parque Simón Bolivar

gardening students from the Trade School of the Historian of the City Office and also for students who are majoring in Natural Sciences at the University of Havana.

This area produces organic fertilizers and plant trees that are used for parks and gardens in the Historical center and other areas. It has a workshop for the elaboration of handcrafts that can have an utilitarian or ornamental function, floral decoration, brushes made of palm fruits, nests for wild nests and biodegradable bags. Also it has a place for obtaining worm humus and 32 flowerbeds for planting vegetables, spices and medicinal plants. All these contribute to a self system of organic production with didactical purposes in city areas, very attractive to visitors.

Visitors can improve their knowledge here and participate in events and festivals of different specialties that are aimed to the protection of the nature and the environment. They can learn how to plant an orchid and a tree, to eat healthy, to breed a pigeon, to know about aquatic plants and the importance of fish in the ponds.

In order to carry out these activities, this garden has a specialized team in communication, popular education, biology, agronomy and informatics; also it has specialists from the City Historian Office, the University of Havana, the Heritage Society and Environment, among other contributors. The Garden Quinta de los Molinos works in order to be an interactive park for learning natural science and environmental education.

Autors collective
SPCMA

GENERAL INFORMATION ABOUT "SOCIEDAD PATRIMONIO, COMUNIDAD Y MEDIO AMBIENTE"

SPCMA (Heritage, Community and Environment Society)

Slogan: For the City, its Inhabitants and the Environment

STRUCTURE AND MISSION:

Founded on May 12 of 2004, the Heritage, Community and Environment Society is a not-for-profit civil organization. The Society has a two-fold mission: first, to cooperate with initiatives that advance the socio-cultural program for the rehabilitation and revitalization of the City of Havana, initially launched in the city's Historical Centre and now expanding throughout the rest of the Priority Zone as designated by the Office of the City Historian; and second, to support the planning and management structures that make this work possible, by promoting them both domestically and in the international arena. To carry out this mission, the Society manages, coordinates and implements a range of projects within three program areas: Heritage, Community, and the Environment.

Members:

Its membership consists of individuals and institutions, both national and international, who are interested in the preservation, rehabilitation, management, development and promotion of the historical, architectural and cultural heritage of the City of Havana, and in the community and environmental issues that affect the City.

SOCIETY GUIDELINES:

- To support the socio-cultural program of the Office of the City Historian.
- To make known, both internally and internationally, the planning and management activities on which this program is based.
- To promote the establishment and development of knowledge and skills in disciplines relevant to the Society's three program areas.
- To support the management and implementation of donations and projects focused on the heritage, community and urban environment of the City of Havana.
- To sponsor and carry out events at both the national and international level.
- To promote research within the Society's program areas.
- To facilitate and carry out the transfer of experience and technology with and among other institutions and countries.

BOARD OF DIRECTORS:

Honorary President: Eusebio Leal Spengler
President: Ana Lourdes Soto Pérez
Full Members: Magda Resik Aguirre
Nelys García Blanco
Ángel Valdés Mujica
José Vázquez Rodríguez
Substitute Members: Pablo Fornet Gil
Martha Rosa Muñoz Campos
Orlando Ramos Blanc

CZECH REPUBLIC

National organization:
General information
Czech Landscape Gardening Association – Czech Green Roof Association (Svaz zakládání a údržby zeleně, z.s. - odborná sekce Zelené střechy (ZeS))
Údolní 33, 602 00 Brno
zelenestrechy@szuz.cz
Managing Director: Ing. Jana Šimečková
President: Ing. Jitka Dostalová
Chapter written by: Ing. Pavel Dostal, pavel@greenville.cz

CURRENT NATIONAL PROJECT

Description: DRN is a newbuilt administrative building in the heart of Prague close to the Czech National Theatre. It features 650 m^2 of intensive green roof and a 5-storey green façade of 262 m^2 with grasses and spring bulbous flowers in national colours. DRN has been awarded first place in the competition Green Roof of the Year 2018.
http://www.zelenastrecharoku.cz/cs/menu/soutezni-dila/budova-drn-objekt-se-smisenymi-funkcemi-vyuziti/

STRUCTURE AND MISSION

The Czech Green Roof Association (Sekce Zelené střechy) was founded in 2013 under the Czech Landscape Gardening Association (Svaz zakládání a údržby zeleně). It comprises natural and legal persons which actively engage in business activities in areas of landscaping and greenery on buildings, particularly green roofs. The Association supports the greening of roofs, walls and other constructions as means of sustainable construction, environmental protection and urban greenery retrofitting. Since its founding, the Association is a member of the European Federation of Green Roof and Wall Associations – EFB. It offers topical seminars and workshops for professionals and the general public, issues expert publications including the Czech green roof standards, organizes the Green roof of the year competition and engages in international projects. In 2018, the Association became a member of the Czech Green Building Council.

SIZE OF THE ASSOCIATION

- 24 individual members (installation companies)
- 7 business members (manufacturers of components)
- 2 associated members (associations)

CURRENT ACTIVITIES

In 2016, the Association implemented a project called "Green roofs – hope for the future II." (Zelené střechy – naděje pro budoucnost II.) supported by the Czech Ministry of Environment. The most significant outcome of the project was the publication of Czech green roofs standards which coins the terminology of green roofs, describes their functions, categorizes green roof types and stipulates the qualitative requirements for each layer of green roof. It also describes suitable vegetation, its maintenance and recommended warranty conditions. The document is first of its kind in the Czech Republic and has been used as a qualitative requirement for a national green roof subsidy program "New green savings".
In the following year, the Association published an overview of measures used to support green roof uptake in European countries and cities. The document was welcomed by municipalities looking to promote urban green infrastructure and climate adaptation.
In 2018, supported by a Ministry of Environment grant as in previous years, the Association continued to spread knowledge about green roofs. As a result, an information portal has been created to serve professionals

as well as general public looking to find expert non-commercial information about green roofs. In the next years, the Association aims to further spread knowledge about

SOME SELECTED CITY GREENING PROGRAMS

The City of Prague, in its Strategy on Adaptation to Climate Change, aims to support the introduction of green roofs and other green infrastructure elements, find ways to encourage green roofs including grant programs, edit current grant programs so that they enable the support of green roofs, establish a "best green roof competition" in Prague.

The City of Brno includes green roofs and green walls within its strategy to lower the risk of heatwaves and the urban heat island effect. Currently, the city is looking to use existing areas for the creation of green roofs and walls. Micro-grants are being considered as one of the measures to achieve this.

The City of Pilsen includes green roofs and walls to help mitigate the risk of flash flooding, and to lower the risks of heatwaves. Green roofs are one of the four climate adaptation measures recommended and elaborated.

The City of Ostrava as with other Czech cities is also looking to use green roofs to reduce the proportion of sealed surfaces and ameliorate the urban heat island. It is considering the development of incentives to help achieve this.

SOME SPECIFIC RELATED HOT TOPICS

195 000 m^2 green roofs have been created in the Czech Republic in 2017, which represents an annual increase of 50 %. 77 % (150 000 m^2) of the total were extensive and 23 % (45 000 m^2) were intensive green roofs. Green roofs are predominantly requested by the private sector.

EFB- EUROPEAN FEDERATION OF GREEN ROOF AND LIVING WALL ASSOCIATIONS

Name: EFB- European Federation of Green Roof and Living Wall Associations (Europäische Föderation Bauwerksbegrünungsverbände)
Address: Wiedner Hauptstr. 63; AT-1045 Vienna, Austria
Type of Organisation: Non-Profit Organisation
Contact Person: Vera ENZI (Spokeswoman), Dusty GEDGE (President), Elisabeth GRUCHMANN-BERNAU (Secretary)
Email: office@efb-greenroof.eu
Website: www.efb-greenbuildings.eu
Phone: +43 650 634 96 31

EFB
EUROPEAN FEDERATION GREEN ROOFS & WALLS
GREENER CITIES IN EUROPE

The EFB was founded in 1997 as a Non-Profit Organisation based with its main office and in Vienna (AT). There are currently 16 national green roof and wall associations that are members of the federation, including Switzerland as an exchange partner:

- Austria (VfB gruenstattgrau.org, GSG gruenstattgrau.at)
- Czech Republic (ZES zelenestrechy.info)
- Germany (BUGG gebaeudegruen.info)
- Germany (VBHS vbsh-ev.de)
- France (ADIVET adivet.net)
- Hungary (ZEOSZ zeosz.hu)
- Italy (AIVEP aivep.it)
- Netherlands (VBB bouwwerkbegroeners.nl)
- Poland (PSDZ psdz.pl)
- Portugal (ANCV greenroofs.pt)
- United Kingdom (livingroofs.org)

• Scandinavia: Sweden, Norway, Finland, Denmark (SGRA scandinavian-green-roof.org, SGRI greenroof.se)
• Spain (PRONATUR. pronatur.es)
• Belgium (BVG)
• Serbia (GRA nazk.org)
• Exchange partner Switzerland (SFG sfg-gruen.ch)

ABOUT US

The national associations themselves consist of over 500 Small to Medium Enterprises and their employees, dealing with manufacturing, supplying and construction of Green Roofs and Walls in Europe. The association is still growing with new members, like Serbia in 2018, and supporting other countries like currently Luxembourg to establish an association. Most national associations have full and extraordinary members from Universities, City Governments, Planning and Architecture bodies related to the association.
Green Roofs and Living Walls of all kinds offer a wide range of different measurable benefits. They are therefore considered as an important element of the Urban Green Infrastructure network especially in densely built retrofit areas of cities. The EFB is supporting Green Roofs and Walls on European level through policy standards, research, promotion, education, knowledge transfer, etc..

MISSION AND CURRENT STATUS

The Federation and its national members actively promote the use of green roofs and green facades throughout Europe. Such technologies are known to provide better quality of life for towns and cities by returning sealed surfaces back to nature and help with Climate Change Adaptation. In 2018 the European Parliament and the Council amended the Directive 2010/31/EU on the energy performance of buildings and the Directive 2012/27/EU on energy efficiency. In this light, green roofs and walls can contribute even more by improving building's energy performances and help meeting other important targets like renewable Energies development.
By organizing urban green infrastructure conferences over Europe (EUGIC) the transfer of knowledge becomes enhanced. In 2015 the first European Urban Green Infrastructure Conference took place in Vienna with great success, followed by Budapest in 2017 and London in 2019. Within the last years working groups supported by the European Commission intensified and Green Roof and wall Technologies became part of Horizon 2020 projects across Europe. Currently the EFB has started a market research initiative to generate a comprehensive market report for the greening industry (2018-2019).

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)
- 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.

GERMANY

BuGG
Bundesverband GebäudeGrün e. V.
Dach-, Fassaden- und Innenraumbegrünung

ABOUT US - A UNION FOR MORE GREEN!

Bundesverband GebäudeGrün e.V. (BuGG) is a merger of the two previously independently acting well-established associations Deutscher Dachgärtner Verband e.V. (DDV) and Fachvereinigung Bauwerksbegrünung e.V. (FBB).
Joining forces into one strong association aims at avoiding double work and investments, and with joined competences of both associations we can act in a more targeted way and increase our impact. BuGG operates both as professional organisation and advocacy group for companies, communities, universities, organisations and all parties interested in building greening (green roofs, green walls and interior greening).

Registered office: Berlin
Business office: Saarbrücken
Founded: 17.05.2018
Members: 330
Activities: all activities in green roofs, green walls and interior greening; predominantly in Germany, embedded into activities of EFB and WGIN

Our targets:

• Increasing the building greening market (increase of direct and indirect funding, building greening must be taken as granted)
• BuGG is the first contact partner in building greening
• Working on image and public relations of building greening
• Initial information and argumentation for architects and building owners
• Technical competence, professional brochures, comments on guidelines
• Market knowledge: data, facts and figures on the German market
• Exchange of experiences and cooperation with neighbouring associations („cross-association Alliance on Building Greening"), including the German-speaking associations from Austria and Switzerland
• Networking services, exchange of experiences
• Practical working aids for members

Strengths and success modules of BuGG:

• Members from different sectors of green roofs, green walls and interior greening.
A multitude of opinions and ideas allow a broad exchange of experiences, and an extensive coverage of wide range of topics
• Project groups, foreign affairs, scouts, ambassadors
• Fact sheets on various fields of specialisation
• Working brochures on various topics, e.g. Safe Trade Separation, Basics of Green Roofs, Guidelines for Local Authorities, Municipal Green Roof Strategies)
• List of root-proof membranes and coatings ("WBB-list")
• Yearbook Building Greening
• Discussion sheet „Nationwide Strategy on Building Greening"
• Cooperation with other trade associations, e.g. BGL, ZVG, BDLA, BDA, DGNB, DWA
• Collaboration with and contacts to policy-makers
• Newsletter (GebäudeGrün-eNews)
• Professional website (including blog and social media): www.gebaeudegruen.info
• Green Roof Symposium in Ditzingen (since 2003), Green Wall Symposium, Interior Greening Symposium and nationwide seminars Green Roof Forum throughout Germany, International Congress on Building Greening in Berlin
• Presence at trade fairs GaLaBau, Nürnberg and Grünbau/Bautec, Berlin

• Research projects
•BuGG contributes to FLL guidelines since many years
• Annual BuGG Green Roof, Green Wall, Interior Greening Awards
• Trade magazine „GebäudeGrün" (previously Dach + Grün; 4 issues p.a.)
• Market report: annual figures published (internal member survey and survey of cities and communities)

At present, BuGG has about 330 members from various trades and industries that are busy with green roofs, green walls and interior greening. As a primary target, BuGG aims at presenting the advantages and possibilities of building greening in front of the widest audience possible. Acting as federal association Bundesverband GebäudeGrün e.V., we have opportunities to create a positive framework and environment „pro green“ that are closed to individual companies.

Contact details:
BuGG Bundesverband GebäudeGrün e.V.

Registered office:
Albrechtstraße 13
D-10117 Berlin
+49 30 / 40 05 41 02

Business office:
In den Birken 11
D-66130 Saarbrücken
+49 681 / 98 80 570

info@bugg.de
www.bugg.de
www.gebauedegruen.info
www.facebook.com/Gebaeudegruen/

www.gebaeudegruen.info/bugg/ueber-uns/ueber-den-bugg/

The Board of Directors of BuGG (v.l.n.r.):
Hans Schmid (Member), Gerd Vogt (CFO), Dr. Gunter Mann (President), Carsten Henselek (Vice President), Helmut Kern (Member)
The former presidents of FBB and DDV Dr. Gunter Mann (left) and Carsten Henselek after the merger on 17.05.2018

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

Roof farming, biodiversity and environmental education. Source: M. Köhler

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.

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.

HUNGARY

Name of local organization: ZEOSZ
(Hunagrian Division of Green Roof and Green Wall Contractors)
Current address: 2822 Szomor, Hegyalja út 52.
email: info@zeosz.hu
Homepage: www.zeosz.hu
Contact person/address: Péter Dezsényi tel: +36309920700 email: pdezsenyi@deepforest.hu
Current president: Péter Dezsényi
Size of the association (number of current members): more than 70 members

ZEOSZ (National Division of Green Roof and Green Wall Contractors) is now a subdivision of the Association of Hungarian Landscape Contractors (MAKEOSZ). The two, originally independent organizations have just merged into a new, larger federation by the beginning of this year (2019), with over 70 contractor members, plus system manufacturers, technical schools, universities, consultants, etc. on board, in order to foster municipalities make their cities greener and healthier all around Hungary.

ZEOSZ has been promoting green roofs and green walls for 20 years now, from media appearances through professional trainings and education to lobbying for local- and country regulations.

Its latest big achievement is the release of the first ever Hungarian green façade and green wall guideline for architects, landscape architects and decisionmakers (2017). The new green roof guideline is about to follow by 2020.

Another noticeable market development is the first ever Hungarian municipality who announced green roofs being mandatory in the entire 12th district of Budapest, for all new and renovated flat roofs. ZEOSZ was contracted as their main consultant.

Thanks to this, with some other progressive regulations, and the dynamic growth of the Hungarian economy, both green roof and green wall markets are growing exponentially in the last 3-4 years. Hungary now has over 3 million m^2 green roofs, and about 200 living walls, mostly made by a new generation of specialised contractors and trained technicians.


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.

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 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.

ArtPrize 2013. Source: Greenroofs.com. Photo Courtesy of LiveWall.

• **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

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)

Freestanding greenwall.
Source: Greenroofs.com. Photo Courtesy of Green Living Technologies International (GLTi).

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 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/

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

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

Bougainvillea is one favorite climber. Lago di Garda (Italy). Source:M. Köhler.

JAPAN

Current adress, email
Tamura building 2F, 3-2-4, Kanda Jinbocho, Chiyoda-ku, Tokyo, 101-0051, JAPAN
Contact person/adress of this chapter saori Ishihara / saori.ishihara@it-chiba.ac.jp

One Picture of a current national project.
The 35 National Urban Greenery Yamaguchi Fair

STRUCTURE AND MISSION, INFORMATION ABOUT CHANGES IN THE LAST YEARS.

The Organization for Landscape and Urban supports a variety of initiatives by citizens, businesses, and public organizations involved in activities to create, protect, and grow greenery, and contributes to the development of green communities through research, information provision, and public awareness activities related to urban greenery. To achieve these goals, The Organization for Landscape and Urban consists of the General Affairs Department, the Planning and Research Department, and the Research Department. Since last year, we have been accepting the attendance of Imperial Princess Mako, commending the winners of the commendation system, and holding "wa" exchange events to promote mutual interaction.

CURRENT PRESIDENT

Hajime Koshimizu
Supporting member corporations and organizations: 118. Individuals: 29

CURRENT ACTIVITIES

1. Public awareness activities: Implementation of public awareness activities, including the National Urban Greenery Fair.
2. Awards and grants: The Green City Award, the Rooftop and Wall Greening Technology Contest and other awards, the Green Environment Plan Grand Prize, Kao's Forestation Program for Everyone, and other grants.
3. Surveys and research projects: Conducted joint research with private companies, commissioned research by the national and local governments, and held an urban greening forum as a venue to present the results of these studies.
4. Evaluation business: Conducts evaluation projects such as the Social and Environmental Contribution Green Evaluation System (SEGES) and the certification of urban greening technologies.
5. Human resource development, information dissemination, and international cooperation: Grants for research to students, disseminates information in journals, websites, etc., and implements international cooperation projects such as international seminars on rooftop greening technology between Japan and Korea.

SOME SELECTED CITY GREENING PROGRAMS

The Organization for Landscape and Urban Infrastructure has given several awards and

Iwaki City of Fukushima Prefecture

Kamakura City of Kanagawa Prefecture

grants. Here, we will introduce the cities that received the "Green City Award" in the "Green City Planning Division" (the development of measures that utilize the characteristics of a region for the greening of urban and regional areas and the conservation of green spaces and the results) in the last three years.

1. Iwaki City of Fukushima Prefecture: Iwaki City is one of the areas affected by the tsunami in the Great East Japan Earthquake. As a part of the rebuilding efforts in the affected coastal areas, the city has planted acorn trees at the tsunami prevention green areas and parks, involving its citizens from seed germination to tree growing activities, to pass on the DNA of the local trees to the new town.

2. Kamakura City of Kanagawa Prefecture: Kamakura City is located next to Tokyo, and is well-known as a tourist destination and its numerous heritage sites. Based on the Greenery Basic Plan formulated here, the city has developed various measures over the years, such as the utilization of the Green Area Preservation System, securing independent financial resources, and awareness-raising activities in cooperation with local citizens and companies.

SOME SPECIFIC RELATED HOT TOPICS

One of the hot topics in Japan is the Urban Green Area Certification System that was established in 2017. Following the approval of a municipal government, this system can be set up, managed, and utilized as an urban green area that can be used by residents. This system can be used as an effort to reduce property and city planning taxes.

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/

Busan City Hall green roof

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.)
  - 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/sub homepage/green/index.html
- http://www.kict.re.kr/eng/rsch/build.asp
- http://www.ggaf.or.kr/eng/business/business _000.html

MEXICO

National organization:
AMENA A.C.
Asociación Mexicana para la Naturación de Azoteas, A.C.
Calle Uxmal 117-402 Col. Narvarte
C.P. 03020, Ciudad de México
Contact: Dr. Gilberto A. Navas Gómez: gnavas.amenamex@gmail.com
Homepage: http://www.amenamex.org.mx

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. AMENA collaborates closely with institutions of higher education such as the Universidad Autónoma Chapingo in the investigation of different aspects of the green roof systems. Its stakeholders include professional designers and builders, architects, developers, environmental consultants, government staff, professors-researchers, students and building owners interested in sustainable design and ecological architecture.

ENVIRONMENTAL STANDARD:

AMENA actively participated in the development of the first Environmental Standard 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. Ten years later, this Environmental Standard was updated and published in the Official Gazette of the Government of Mexico City on November 30, 2018.

INTERNATIONAL COLLABORATION:

AMENA is a founding member of the World Green Infrastructure Network (WGIN). It continues its international cooperation with WGIN and currently provides with Ulrike Grau from Chapingo University a board member.
In 2010, AMENA organized the annual WGIN Congress in Mexico City. It was the first World Green Roof Congress ever held in Latin America. Approx. 500 attendees participated

and the congress featured international speakers with emphasis on Latin American speakers as well as Mexican presenters.

ACADEMIC RESEARCH INSTITUTIONS WITH GREEN INFRASTRUCTURE RELATED RESEARCH:

- Universidad Autónoma Chapingo. http://www.chapingo.mx
- Universidad Nacional Autónoma de México:
  - o Facultad de Arquitectura del Paisaje. http://www.arquitectura.unam.mx
  - o Instituto de Biología. http://www.ib.unam.mx/
- CIIEMAD-IPN. http://www.ciiemad.ipn.mx/Paginas/Inicio.aspx
- Colegio de Postgraduados. http://www.colpos.mx
- Universidad Autónoma Metropolitana. http://www.uam.mx/

CURRENT GREEN ROOF ACTIVITIES IN MEXICO:

About 10,000 m² green roofs are being built each year of which about 80% are extensive naturation systems and 20% more intensive roof gardens. Over the past six years, the local government of Mexico City through the Secretary of Environment and in collaboration with the agronomic university Universidad Autónoma Chapingo fostered the installation of approximately 4000 m² of green roofs each year.

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 incentive program. Incentives for green roofs range between 10 and 15 % off property taxes. Mexico City also has several projects for the installation of green roofs in public buildings such as schools and hospitals. Recently, green roofs with biodiversity designs are being promoted.

Living walls are also becoming more popular despite being rather expensive and having to cope with problems with the proper selection of vegetation for external walls, water management in relation to evapotranspiration and application of nutrients. They are majorly implemented by companies as showcases.

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 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

POLAND

Current address and email
pl. Grunwaldzki 24a, 50-363 Wrocław, Poland, www.psdz.pl

Contact person/address
marta.weber.s@gmail.com

Logo of the Conference on the occasion of the decade the existence the Polish Green Roof Association

STRUCTURE AND MISSION, INFORMATION ABOUT CHANGES IN THE LAST YEARS.

Polish Green Roof Association (PGRA) gather together 106 members interested in green roofs and living walls problems. They are researches, architects, consultants, appraisers, inspectors and technical supervisors, professional press journalists, lawyers, employees of governmental and municipalities organizations as well as students.

Polish Green Roof Association is a member of the Federation of Engineering Associations – FSNT-NOT, which is Polish organisation of over 170 years history. This organization unites and co-ordinates 39 professional Associations of all branches of engineers and technicians in Poland (ca. 100 300 individual members altogether). From 2014 Polish Green Roof Association is a member of EFB (European Federation of Association of Green Roofs and Living Walls) and from 2017 is a member of WGIN (World Green Infrastructure Network).

PGRA inspires specialists involved with green roofs and living walls problems and serves as the source of information, news and resources dealing with planning, execution and upkeeping of green roofs and living walls as well as the place where everyone can share their experience. The aim of the Association is to spread highly specialized knowledge by organising training courses and conferences. Very important and common activity of all members of the Association is the cooperation with municipal offices, contributing to creation of local and/or national policy concerning importance of green infrastructure to cities. An equally important purpose is to create nationwide guideline that will stimulate installation of bigger number of green roofs and living walls on new and existing buildings and will helps to understand how many benefits this kind of urban greenery can brings. Therefore, in recent years Association closer co-operates with municipalities.

CURRENT PRESIDENT:

Marta Weber-Siwirska (PhD, assistant professor at Wroclaw University of Environmental and Life Sciences)

SIZE OF THE ASSOCIATION:

106 members including 18 supporting members

CURRENT ACTIVITIES

In the current year (2019) Polish Green Roof Association leads the following actions:

The Visegrad Group project – this is second joint project Associations from Czechia, Hungary, Slovakia and Poland. These adjacent Central European countries have similar history and current economic situation.

Therefore it is quite easy to conduct joint projects. In 2019 the representatives of these countries will visit one city in each country. They are the examples of smart city in ecological meaning and showed solution are possible to implicate in every city belonging to Visegrad Group.

Conference on the occasion of the tenth anniversary of the existence the Polish Green Roof Association – the most important event for Polish Green Roof Association this year. All board members and some other members of the PGRA are involved in preparation of this international conference. During this conference Association wants to present the current situation of green infrastructure in Poland and in the World. It would help some Polish stakeholders to take proper decisions to create more green roofs and living walls in their cities.

Besides above mentioned activities the members of Polish Green Roof Association have been invited by other organisations to present lecture and seminars in different conferences and training courses.

SOME SELECTED CITY GREENING PROGRAMS

For now, there is no national policy on green infrastructure in Poland yet. Some cities like Warsaw, Krakow, Lodz and Wroclaw published standards for urban greenery. These documents do not mention the green roofs and living walls, but sometimes indicate in which case they can be used. In addition, inhabitants of Wroclaw can obtain a tax reduction if the building where they live has green roof or living wall.

PORTUGAL

ANCVGREENROOFS.PT
ASSOCIAÇÃO NACIONAL DE COBERTURAS VERDES

HISTORY OF YOUR ASSOCIATION:

The Portuguese Association for Green Roofs, existing since 2015, is a non-profit organization, which aims to promote green infrastructure in cities, especially those that can be installed on buildings (new or pre-existing) such as green roofs, highlighting their enormous importance, and the numerous contributions they can give to the possibility to create healthy, sustainable, biodiverse and resilient urban territories.

BOARD MEMBERS OF YOUR ASSOCIATION

President: Paulo Palha.
presidencia@greenroofs.pt
Vice-president: Cristina Matos Silva.
cmsilva@civil.ist.utl.pt
Treasurer: Ana Mesquita.
anamesquita@landlab.pt
Co-opted members of direction:
Beatriz Castiglione.
beatrizcastiglione@gmail.com
Cristina Calheiros.
cristina@calheiros.org
José Avila e Sousa.
avilaesousa@gmail.com

VISION AND MISSION STATEMENT

In the last decades, problems such as pollution, soil impermeabilization indexes, density and quality of buildings, energy inefficiency and loss of biodiversity, have been aggravated, at the same time that extreme (and increasingly frequent) climatic phenomena occurs, such as heat waves / drought and extreme precipitation phenomena.
The evidence of many services that green roofs can bring to the urban environment makes them part of the environmental strategy of modern cities, already an obligation in cities like Copenhagen and highly encouraged by a number of worldwide governments.
Rainwater retention and peak flood delay, thermal insulation, protection and increase of waterproofing life, creation of biodiversity niches, CO_2 capture and oxygen production, associated with the improvement of the urban landscape and the appreciation of the buildings, are part of the set of arguments of undeniable value that make it unquestionable the need to introduce the green roofs in the cities, demonstrating the urgency to consider vegetation as a mandatory building material.

CONTACT DETAILS OF THE ASSOCIATION E-MAIL, WEBSITE ADDRESS / COUNTRY

e-mail: baseancv@gmail.com
Website address: www.greenroofs.pt

PROFESSIONAL IMAGE AS ASSOCIATION

NATIONAL RESEARCH

The Fifth Façade Project

The Fifth Façade Project (PQAP), a project created by Paulo Palha, President of the Portuguese Association for Green Roofs (ANCV), is a project between ANCV and the Porto City Council. Its objective is to define the best way to include green roofs in the environmental and urban strategy of the city of Porto.

The project began in August 2016 and was attended by a large group of people from different departments of the Porto City Council, as well as different universities, foreign municipalities, the European Federation of Green Roofs and Walls Associations, and the World Green Infrastructure Network, among other institutions.

PQAP represents an important step in the history of the Green Roofs movement in Portugal, since it's the first time that a City Council manifests its desire to include green roofs in the urban planning documents of the city. The project was also essential to give ANCV executive capacity and increasing visibility. On the other hand, it symbolizes the interdisciplinary character of the association, since it has been necessary to promote the intervention of research groups, companies, and municipalities; exactly the network created by ANCV.

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.

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: 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.

NORWAY

Green roofs have a long-standing history in Norway. For centuries, Norwegians have used 'torvtak' sod roofs as a mechanism for insulation against the cold winters. Today, the tradition is still strong and these sod roofs can be found both in cities and throughout the countryside. Other types of green roofs, such as extensive sedum roofs, are being used increasingly more in Norway. This reflects the improving understanding of green roofs as a beneficial tool for the urban environment and challenges in climate change rather than just as a symbol of national heritage.

Norsk Forening for Grønne Tak (NFGT – Norwegian Association for Green Roofs) is the primary independent professional body supporting members who want to promote green roofs in the country. Many of the green roofs suppliers are small businesses scattered throughout the country, and this centralized body is of growing importance for those interested in preserving sod roof heritage as well as those interested in increasing the presence of urban green roofs and other green infrastructures. NFGT is looking to the future by participating in the creation of national standardizations with the Norwegian Bureau of Standards, uniting small and large businesses in various supplier fields, and promoting progress in the budding green roof sector.

From 2009 to 2014, in a project titled 'Cities of the Future', urban municipalities in Norway contributed significantly to the development of green roofs. Seven of its largest cities installed green roofs for demonstration and research purposes, leading the way for urban strategies as well as a better understanding of local stormwater mitigation. Two major papers were made from the work – 'Urbanization - Green roofs in urban areas. Field experiments runoff water' with SINTEF and Nittedal Torvindustri and 'Green roof – Results from the knowledge acquisition project' with SINTEF, Bioforsk, NMBU, and the City of Oslo. Following this work, the City of Oslo announced a plan to develop a green roof policy similar to other European cities, such as Copenhagen. The growing interest in green roofs has encouraged further developments like a seminar series led by the Norwegian Association for Landscape Gardeners (NAML) and a Norwegian translation of Germany's FLL guidelines.

Though Norway may have a slowly growing green roof market currently, its historical use contributes to quality developments in an area well-poised for expansion.

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

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

SPAIN

National organization:
PRONATUR.
itdUPM. ETSIAAB. Avda. Puerta de Hierro 2. Madrid 28040. Spain
www.pronatur.es

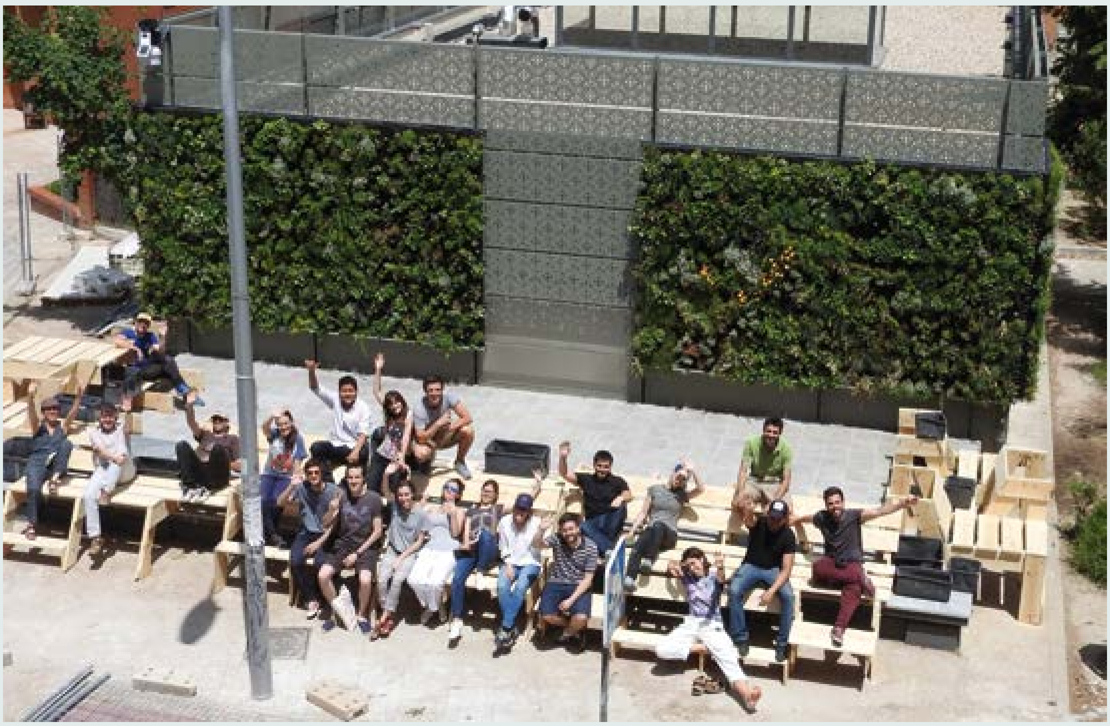
Contact person
PRONATUR: Julian Briz.
julian.briz@upm.es; julian.briz@hotmail.com

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 1992 with the collaboration of IASP (Humboldt University Berlin).

b) Board of directors 2019:
President and founder: Julián Briz. Emeritus Professor.
Vice President: Joaquín Sicilia. Entrepreneur. Firm Sicilia Architect.
Secretary: Manuel Pasquín, Entrepreneur.
Treasurer: Beatriz Urbano. Professor. Universidad Valladolid.
Directors:
- Isabel de Felipe. Honorary Profesor. itdUPM. Madrid.
- Francesca Oliveri. Professor UPM. Madrid.

The goal of PRONATUR is to promote and coordinate activities between University, Administration and firms for improvement of nature in urban environment with socioeconomic dimensions.



Some of the guidelines for PRONATUR are focused on:
- Greening buildings
- Green streets and open spaces in the city
- Quality environment (air, acoustic)
- Urban agriculture
- Health and recreation
- Integration of urban society

As a way to promote urban agriculture in 2012, it was founded in coordination with Foro Agrario the Observatory of Urban Agriculture

CURRENT PRESIDENT

Julián Briz. Emeritus Professor.

SIZE OF THE ASSOCIATION

Including the Observatory of Urban Agriculture, about 200. There are academics, technicians, entrepreneurs, practitioners and neighbourhood organizations.

CURRENT ACTIVITIES

Members of international institutions:
- 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 the board of Directors of WGIN (World Association)
- Since 2017 Member of the board of Directors of EFB (European Association)

a) National and international seminars and congresses:
- 1995. International seminar in Cottbus (Germany) at the Bundesgartenschau = BUGA
- 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: Toronto (Canada), Mexico DF (Mexico), Indore (India), Hangzhou (China), Nantes (France), Nagoya (Japan), Sydney (Australia), Bangalore (India).
- 2010: Contribution and discussion in the Urban and Peri-urban Agriculture and Urban Planning (FAO-ETC)
- 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.

ACADEMIC AND RESEARCH ACTIVITIES:

In 1994, from the City Hall of Madrid, PRONATUR received the award in the field of "Urban Environment".
Three experimental green roofs were created in collaboration with the City Halls of Berlin

and Madrid (1993), UPM (1996) and the Ministry of Industry and Energy and the firm Intemper (1999)

- Several PhD, Masters Theses and academic projects
- Member of the team coordinated by the Technical Agricultural School of Barcelona publishing the handbook of "Standard construction on green roofs"
- Since 2012 PRONATUR is an active member of the Innovation and Technology for Development Centre (itdUPM):
  + Laboratory Bioclimatic Architecture and Urban Agriculture (LABAU)
  + Climat Reality Prize Award 2018
  + Massive On line Open Couse (MOOC) about "Ciudades verdes, naturación y agricultura urbana" (2018), with more than 2000 participants
  + Project of "Vegetation towers designed as urban modules for cleaning the air of cities"
  + Projects of green urban infrastructure with the City Hall of Madrid and the City Hall of Lugo.
  + Project of greening the Matadero Space with Madrid Town Hall and itdUPM.

SELECTED NATIONAL SCIENTIFIC PUBLICATION

a) Books:

- Naturación Urbana: "Cubiertas ecológicas y mejora medioambiental" Mundiprensa (1999, 2004)
- Green Cities in the World, WGIN, PRONATUR (2014, 2015)
- Agricultura Urbana Integral, edited by the Ministry of Agriculture and PRONATUR (2015)
- Vertical Urban Agriculture edited by itdUPM and PRONATUR (2017)
- Multifunctional Green Urban Infrastructure (2019 in print)

b) Proceedings and public declarations on green urban infrastructure seminars (Havana, Quito, Cartagena Indias, Berlin, Madrid, Río Janeiro)

SELECTED CITY GREENING PROGRAM

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 no official statistics. However, in many Spanish cities there is a growing trend in green buildings. In the Madrid area, some of the more significant projects are the Barajas Airport, Santander Financial City, Caixa Forum, hospitals, rooftop farms, and others.

SOME SPECIFIC RELATED HOT TOPICS

- Environmental impact of green roof and wall
- Urban agriculture multifunctions
- Carbon and energy footprint evaluation under the focus of green urban areas.
- Roof top farming.
- Improve the coordination of synergies between actors (public and private sector) involved in greening cities activities
- Urban Energy and water management.
- Socioeconomic impact of green urban infrastructures

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.

RECOMMENDED NATIONAL WEBPAGES:

http://www.greenroof.org.tw

Roof garden as Art installation. Source: M. Köhler

THE NETHERLANDS

National organization:
AVereniging Bouwwerk Begroeners VBB
Industrielaan 15 B
3925BD Scherpenzeel - Netherlands
Phone +31 33.277 3404
Mail: secretaris@bouwwerkbegroeners.nl
Website: www.bouwwerkbegroeners.nl
The VBB is a member of the European Federation of Building Greenworkers: EFB and the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau: FLL .

SUSTAINABILITY AND CLIMATE CHANGE

A clean, green and healthy country where sustainability contributes to a strong economy. This is the ambition the Dutch VBB wants to work on for sustainability. Reducing carbon emission, preparing for the consequences of climate change, improving air quality and reducing noise are the main topics in the Netherlands. The VBB (and their green roofs and green walls) are at the national level key player as the association with experienced members. VBB = Vereniging Bouwwerk Begroeners which means "Building Greenworkers Association". The VBB constitute a big club but with an experience that matters, some members have been working as the largest in its field in Europe or even worldwide. The motto is "knowledge by organization ".

MORE GREEN AREAS

Creating more green areas in and around the cities will contribute to many of the key targets. More plants will enable the cities to store more rainwater and in this way prevent water damage (green roofs and green facades). Planting trees, bushes, shrubs, green facades, roof gardens and green roofs makes the cities more attractive and helps limit the consequences of rises in temperature, which in turn reduces the risk of heat stroke (heat-induced illness). Extra vegetation is good for public health as the view of and proximity to planted areas reduces stress and trees and bushes also mask traffic and industrial noise. Finally, green roofs not only help with water storage but also they save energy and increase the life span of the roof.

Urban parks and gardens can be used to produce healthy and sustainable food. More plants in public areas, on roofs and on facades will also make cities a more pleasant place in which to live. By additionally creating high-quality parks and developing ecological routes and nature parks around we also stimulate the potential for recreation and leisure activities as well as improving biodiversity.

KNOWLEDGE

The VBB programme is based on knowledge of the members such as roofing contractors, green roof manufacturers & suppliers, architects and landscape designers who are active in the green roof industry.Innovative green solutions and international collaboration will enhance the quality of life in the Netherlands.

In the long term we would like to see 'trees and green areas' become a standard part of instruments targeting the fields of health, noise control, climate, water storage and air quality. Green roofs, living roofs and brown roofs are and will be an increasingly important technology. The ecosystems services that are provided by green roofs and living roofs will be especially important in regard a reduction in the Urban Heat Island [our summers are predicted to get much hotter] and help reduce the impact of flash summer storms that are predicted to increase as the climate changes.

We intend to demonstrate that an intensely urban and industrial environment can accommodate biodiversity.
The VBB is a member of the European Federation of Building Greenworkers EFB and the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau FLL . The members of the VBB-association do work on development and realization and do have various types of green roofs and facades e.g. sedummixmats, greenrooftiles.

HOW WILL THE GOALS BE ACHIEVED?

By putting the right plants in the right place. We are continuing our policy of planting more trees, bushes and other vegetation in our nation. This is something we have been doing for several years now. Government, cities, residents, farmers, shop keepers, institutions and local councils are being asked more than ever to contribute to making this goal a reality. We are also trying to cooperate with the district waterboards to add to the vegetation in the form of more green roofs and green facades to create an alternative form of water storage. Many residents and entrepreneurs are already contributing to our urban nature goals. In Amsterdam and Rotterdam groups of residents and entrepreneurs are setting up various urban farm initiatives. We match the demand with other ideals such as sustainably managed natural areas around the cities, urban parks and gardens or involving young inhabitants via nature and environmental education. Some private individuals and entrepreneurs have, with the aid of green roofs subsidy schemes throughout the Netherlands, already constructed lots of green roofs and green facades.
For standardizing the quality of green roofs the VBB is working (with others) on an official standard: the NEN-norm, the first official standard in this area in Europe. NEN is NEderlandse Norm, EN is the European Norm; like ISO voor International Organization for Standardization. Meanwhile the VBB has it’s own directive: VBB Richtlijn Begroeide daken 3.1.
The information in the directive green roofing provides a summary of materials, systems and or products that are used in green roofs.

Information is also given for testing, evaluation of conformity.

REFERENCE PROJECT DUTCH MARKET - PASSIVE HOUSE WERKHOVEN

In cooperation with architect Voss and construction company Van Rijn BV - knowledge leader in the field of sustainable concepts –a green roof was realized on top of this Passive house in Werkhoven, The Netherlands. For this green roof vegetation blankets from Sempergreen were used. Sempergreen is the world's largest developer and supplier of vegetation blankets for green roofs. The house was completed in 2013.

Passive Houses are very energy-efficient homes, where consumption of space heating is less than 15 kWh / m² gross per year. It results in an ultra-low energy building, herewith reducing its ecological footprint. Passive design is not an attachment or supplement to architectural design, but a design process that is integrated within the architectural design.

Research shows that extensive green roofs reduce temperature fluctuations, bringing average temperatures down, while covering roofs with Sedum plants - rather than black roofs - reduces the energy required to heat and cool buildings. For example, flat roofs without greenery can be up to 21 C warmer than green roofs.

The design of this passive house is oriented to the sun and is executed with good insulation and advanced installation methods. A conventional heating system is therefore unnecessary.

The property is largely made of wood, since this material is one of the few materials that is in its core a natural and fully Cradle to Cradle product. The very low power consumption is combined with a very high quality and comfortable indoor climate.

sempergreen®

Sempergreen: www.sempergreen.com
Architect Voss: http://www.abvoss.nl/
Construction company Van Rijn BV: http://www.bouwbedrijf-vanrijn.nl/algemeen/projecten%20&%20referenties/Nieuwbouw/Particulieren/Passieve+woning/?art=2013-109#ad-image-0

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:

Green Roofs for Healthy Cities (GRHC) is a non-profit 501(c6) incorporated in 2004 the state of Virginia but serving markets in Canada and the United States. This member based and supported organization provides a variety of products and services designed to support the development of the green roof and wall industry. We advocate for supportive policies, hold regular events, conduct professional training, develop standards, provide awards of excellence to project designers, researcher and advocates and support the international movement to develop green roofs and walls. GRHC also works closely with its charitable arm, the Green Infrastructure Foundation, 501 (c3) whose mission is to develop the green infrastructure industry more broadly primarily through education.

The current board of directors of Green Roofs for Healthy Cities for 2019 are as follows:

- Matthew Barmore, GRP, MBA
  Greenrise Technologies, Chair GRHC
- Jeffery Bruce, GRP, FASLA,
  Jeffery L. Bruce & Co. LLC, Past Chair
- Peter Lowitt,
  Devens Enterprise Commission, Past Chair
- Steven W. Peck, GRP, Honorary ASLA – Ex officio
  Founder and President
- Christian Mahlstedt, LEED AP, GRP, Treasurer
  Gingko Sustainability
- Ann-Neil Cosby
  McGuire Woods LLP, Attorney
- Dr. Hamid Karimi
  DC Department of Energy and Environment, Policy Committee Chair
- Dr. Reid Coffman
  Kent State University, Research Committee Chair
- Michael Krause
  Kandiyo Consulting, LLC, Green Infrastructure Foundation
- Joe Di Norscia
  Rooflite, Member-at-Large
- John Robinson, CSI/CDT, GRP, RRO
  Sika Sarnafil, Member-at-Large
- Melissa Daniels, GRP, CNLP
  Plant Connection, Green Walls Chair
- Elizabeth Hart, GRP, CDT
  GRiT, Green Roof Professional Chair
- Jeff Joslin, APA
  Director, Current Planning, San Francisco, Policy Co-Chair.

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, GRP, Founder and President, GRHC
speck@greenroofs.org
Rohan Lilauwala, GRP, Program Manager, GIF
rlilauwala@greenroofs.org

HOMEPAGES

www.greenroofs.org
www.livingarchitecturemonitor.com
www.livingarchitectureacademy.com
www.greeninfrastructurefoundation.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
San Francisco, California: Better Roofs Ordinance requiring green roof and/or solar panels 2017.
Portland, Oregon: Mandatory green roof requirement for new buildings in City Central. 2018
Denver, Colorado: Mandatory green roof requirement for new and existing buildings. 2018.

MEMBERSHIP:

Founding member of WGIN.

FURTHER ACTIVITIES

Online Professional Courses

Green Roof Professional (GRP) Training is now online, as well as the GRP exam at the living architecture academy. Three days of lectures, 1000 plus pages of digital resource manuals and a 100 question exam are all available online.
Additional courses are available in subjects such as Advanced Maintenance, Net Zero Water Design and Installation, Green Wall Design 101, Green Infrastructure Monetary Valuation, and Biophilic Design. See www.livingarchitectureacademy.com for course descriptions and prices.

LAPT Performance Rating System

In 2018 GRHC and the Green Infrastructure Foundation launched the beta version 1.0 of the Living Architecture Performance Tool (LAPT) which is a 110 credit system for evaluating the performance of a green roof, wall or any combination thereof. The framework is flexible to different climates around the world, and it also has 10 innovation credits built into it. There are a number of pre-requisites that must be obtains in order to achieve third party project certification – certified, silver, gold and platinum. More than 10 projects are going through the certification program. The LAPT can be used by designers to improve their designs, by developers and owners to improve performance and by policy makers. It is based on the same structure as the USGBC's LEED program and Sustainable Sites. To download a free copy of the LAPT go to www.greeninfrastructurefoundation.org A revised version 2.0 of the LAPT will be completed in 2020 after the initial certifications are completed in 2019.

Events

Across North America we organize events to train and develop policy in support of green roofs, walls and other form of green infra-

structure. Each spring, we organize Grey To Green, a conference on green infrastructure in Toronto, Canada. Every year we also hold an international green roof and wall conference called CitiesAlive. To find out about these please visit www.greenroofs.org The next CitiesAlive conference will be in Philadelphia in 2020.

PUBLICATIONS

Each quarter we publish the Living Architecture Monitor, now in its 20th year. This digital journal includes interviews with experts, new products, new project designs, award winning projects, policies and more. The digital version is free and can be downloaded at www.livingarchitecturemonitor.com Back issues are available online.

We publish the Green Pages: Green Roof and Wall Industry Directory which is available for download under our "Resources Section" of the www.greenroofs.org web site.

GRHC also publishes an estimate of green roof and wall development on an annual basis, a summary of which is also available on our web site. Although not comprehensive, these surveys do provide a snap shot of where the industry is developing across North America.

Conference recordings for CitiesAlive and Grey to Green, which consist of powerpoints synced to audio recordings, are available for purchase, as well as various training resource manuals, at our Green Infrastructure Store – www.greenroofs.org/greeninfrastructure-store/

SERVICES

The Green Infrastructure Foundation has developed a unique program that combines the redesign of a community park, district or building complex using green infrastructure, with a detailed cost and benefit analysis of the outcome. This Green Infrastructure Charrette program has worked with communities from Toronto to New York and Seattle. For more information and to read some of the Charrette Report see: www.greeninfrastructurefoundation.org

GREEN ROOF RESEARCH INSTITUTIONS IN NORTH AMERICA

There are many green roof research institutions in North America. In 2018, we launch the Centers of Regional Living Architecture Excellence with a number of prominent research institutions to further advance research, teaching and policy development. The new Centers of Excellence and leading academics are as follows:

Southern Illinois Center of Excellence

Southern Illinois University Edwardsville, Dr. Bill Retzlaff, Associate Dean, CAS, Distinguished Research Professor, Biological Sciences

New Jersey – Stevens Institute of Technology Center of Excellence

Stevens Institute of Technology, Dr, Elizabeth Fassman-Beck, Associate Professor, Department of Civil, Environmental and Ocean Engineering

Colorado Center of Excellence

Colorado State University, Dr. Jennifer Bousselot, Special Assistant Professor, Department of Horticultural and Landscape Architecture;
University of Colorado Denver, Leila Tolderlund, Assistant Professor
College of Architecture and Planning.

Greater Ohio Center of Excellence

Kent State University, Dr. Reid Coffman, Associate Professor, College of Architecture and Environmental Design;
University of Cincinnati, Professor Virginia Russell, Director, Horticulture/Landscape Architecture/Professor Landscape Architecture and Dr. Ishi Buffam, Department of Biological Sciences; Heidelberg University, Mark E. Mitchell, Biological and Environmental Sciences.

The objectives of these Centers of Excellence are as follows:

- To support the development of living architecture research, professional training and policy development at a regional scale;
- To aid academic/industry/policy interaction in ways that can better address regional environmental, market place, regulatory, and climatological realities;
- To provide venues to hold GRP training courses, continued GRP education, and general membership drives;
- To engage more students to support the employment needs of the growing industry through membership and training;
- To provide continuing education GRPs and support industry professionals to meet and advance policies within their region;
- To strengthen dissemination via the Journal of Living Architecture by supporting the research work completed at the centers;
- To facilitate academic meetings and seminars; and
- To provide support to faculty for funding student research, directly with seed funding, and through industry partnerships.

CURRENT TRENDS:

Biophilic design theory and practice as it pertains to buildings and communities.

SELECTED NATIONAL SCIENTIFIC PUBLICATION

GRHC has established a per reviewed online scientific journal called the Journal of Living Architecture (JLIV). It is focused on green roof and wall research and it is free to access at: www.livingarchitecturemonitor.com/jliv

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
www.livingarchitectureacademy.com

The book is a fruitful collaboration between institutions, organizations, enterprises and expertise's in green urban infrastructures under the common idea that Humanity needs a sustainable development, where urban areas has to look for ecosystemic services. Solutions to many problems may resolved under the nature experience which for thousand years have been adapted to the environment.

We present the experience of specialist in a broad range of disciplines, which deal with topics as mimicry, energy saving, landscape or urban planning.

Along 352 pages the publications includes 17 chapters with 30 authors from 17 countries. There is a special section, which describes international and national organization from 30 countries. Photography color, tables and graphics facilitate the lecture and understanding of the topic green urban infrastructure.

WORLD GREEN INFRASTRUCTURE NETWORK
vegetation makes it possible!

PRONATUR

978-84-92928-96-5