For hundreds of years people have delighted in climbers and creepers rambling up walls. Roses, ivies, wisterias, honeysuckles and many other climbing and clinging plant species have softened buildings and perfumed the air whilst at the same time providing food and some habitat for insects and birds. They have even provided some climatic moderation as rain and thermal screens. In the second decade of the 21st century climate change and air pollution have become key drivers and it is no wonder that living walls have become increasingly important providers of the ecosystem services that are required to make our cities better places for people and for nature. There is not enough land in our cities to provide the horizontal greening that we require to diminish the urban heat island effect, to provide microclimatic and pollution amelioration and mitigation or to ensure that nature is catered for. Neither is there enough space for growing local food. Living walls can be an integral part of the solution. By growing plants vertically, on buildings and indeed within buildings, we can help to ensure that we improve the quality of our cities and the quality of life and well-being for the people and wildlife that inhabit them.

This conference provides a small step in providing the conversations that are needed between researchers, designers and industry around living walls and the ecosystem services they provide. As knowledge grows we will need to talk and publish even more. Many thanks to all those who have contributed to this conference through the dissemination of their research and to the attendees who are important contributors in the drive to making our world a better place to live in.

Benz Kotzen | Sarah Milliken | Shelley Mosco
University of Greenwich Green Roofs and Living Walls Centre
Department of Architecture and Landscape

Keynote lectures

Oral presentations

Posters

Workshops

Living Walls – Art or Function? | George Irwin

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This presentation is a perspective of living walls in relation to the state of the industry, technology development, applications and predicted advances. The living wall industry is in its infancy yet remains complementary to an aged preceding cousin, the green roof. Living walls are still finding specificity for applications that may or may not advance and protect our values, assets and basic needs. There is a natural behaviour by humans to engage with the environment, better known as biophilic theory. Some living walls are simple advertisements dedicated to drawing attention as living art. Other design intent impacts environmental remediation, biophilic design, advanced science and agricultural vitalization. Are living walls really design specific and is the dynamic technology able to adapt to project specificity, or is the living wall gold rush degrading the quality, the industry and the ability to specific design intentions? The discussion also defines the health threats that involve synthetic applications such as hydroponic living walls and the use of synthetic fertilizers, algae build up and mould: can they be considered as part of an overall biophilic design intent? Is your living wall or roof a threat or a benefit? This perspective is sure to create additional dialogue and advanced discussion.

George Irwin is the founder and President of Green Living Technologies International LLC (GLTi). He is also a global pioneer in vertical agriculture with a focus on education and training. A published author and the featured 'Green Wall Editor', George is also a leading resource and authority for green wall and roof technologies around the world. Prior to founding GLTi, George was a landscape contractor for over two decades. He holds a degree in education and maintains his passion for out-of-the-box learning, combining his love for the environment and zest for learning into a growing global business. George personally oversees all green wall and roof education, integrating state-of-the-art technology and ideas into a continuously evolving educational and training curriculum. Annually, he teaches hundreds of new green technology experts in green roof and living wall manufacturing, installation, growth, and maintenance. His mission is to help create sustainable solutions to the challenges of food insecurity and the dearth of job opportunities for at-risk youth in inner cities through vertical farming.

Solar Leaf | Martin Pauli

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Solar Leaf represents the first façade system capable of cultivating microalgae. It generates heat and biomass as renewable energy sources while absorbing carbon dioxide. The system features structural glass photobioreactors which are used as external cladding elements and dynamic shading devices. The system is fully integrated in the building services system in order to harvest, distribute and store solar thermal heat on site. The advantage of biomass is that it can be stored with virtually no energy loss, moreover there is no additional land use required. The system has been developed within a consortium, comprising designers, biologists and manufacturers. After the successful implementation at the beginning of 2013, Solar Leaf has been intensively monitored in order to understand correlations between energy and technical performance and the user acceptance. The results are very promising, the system worked constantly, minor technical challenges have been solved and biomass and heat was generated. The next step will be to incorporate the system into a larger context so that it actively contributes to self-sustaining smart urban districts.

Martin Pauli works for Arup Deutschland GmbH. His background is in design and he holds a Master's degree in architecture with emphasis on the development and application of new materials and systems as well as the implementation of circular economy principles into the built environment. Martin's current professional focus is on living materials and their integration into building systems and components, particularly how they can contribute to self-sustaining urban ecosystems. His work portfolio includes a large variety of projects differing in typology, scale and geography, all related to integrating sustainable building operation, a seamless user experience and state of the art technology in the design. Working at the interface between Materials Consulting and Arup's Foresight and Innovation team enables Martin to combine his profound technical knowledge with his ability to analyze and understand future trends and their potential impact on the built environment.

Green walls and urban insects

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The value of urban green walls for insects was investigated using 29 green façades (GF) – walls with climbing plants and/or wall shrubs – and 22 living walls (LW) – plants grown in irrigated modules. Insects were suction sampled in 2011 for GF and in 2012 for LW. They were compared to 29 bare walls and 4 green screens (free-standing, ivy-covered mesh). Green wall characteristics (e.g. vegetation surface area, aspect, plant species richness and density, type of foliage, type of living wall system) and indirect factors (e.g. surrounding vegetation, vehicle traffic and pedestrian traffic volumes, seasonality) were studied.

6404 insects were found on GF (11 orders, 86 families and 208 'species') and 1399 insects on LW (9 orders, 61 families and 137 'species'); 360 insects were found on green screens (6 orders, 37 families, 55 'species'). Insect fauna as a whole showed little variation in abundance and richness. At the order level, differences were evident: Coleoptera were influenced by wall surface area, foliage type, wall height, surrounding vegetation and traffic volume; Diptera were influenced by the vegetation composition, richness and density, foliage type, wall height, wall age, living wall system, and season; Hemiptera were influenced by the vegetation surface area, vegetation composition, foliage type, wall height, living wall system, surrounding vegetation, and the season; and Hymenoptera were influenced by the wall height and the pedestrian traffic.

In conclusions, (i) the local environment has an effect on insect populations of green walls, and (ii) the characteristics of green façades and living walls influence the species groups found on them and, as such, hold the potential for influencing the design of planting schemes to favour particular target groups.

Implications of bird use of urban hedges for the design of living walls

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There has been a vast increase in our understanding of the importance of green infrastructure to both human and ecosystem health in recent years. Urban hedges are a significant component of our current urban greening and their impact on urban biodiversity is not well documented. Where do hedges 'fit' within our definitions of urban greenery? And how important are they in our space-starved inner city areas?

This project investigates part of the role that hedges play. Rural hedges provide vital habitat and food for rural birds; do urban hedges provide a habitat or food source for our urban bird populations? The aim is to determine if different species of urban hedge support different birdlife, and whether other associated environmental factors also have an influence.

Surveys were carried out on hedges of three different species: hawthorn (*Crataegus monogyna*), beech (*Fagus sylvatica*) and privet (*Ligustrum vulgare*) in a variety of locations throughout the city of Stoke-on-Trent in 2014. Bird species and behaviour were recorded in a series of observational surveys. Hedge condition surveys were undertaken, as were surveys of the environmental factors in close proximity to the hedge. Those factors studied included: proximity to roads, the amount of vehicular traffic, hedge condition and management and adjacent land use. Significance testing was undertaken to identify if there is a difference in the number and species richness of birds and whether nesting behaviour was observed in the different hedge species. Multiple regression analysis was carried out to identify those factors with the greatest impact on the abundance and species richness of birds.

The findings are discussed in relation to hedge and green wall design, where hedges fit within the definition of green walls, and the comparability of results from different green wall types.

Effects of a bio-barrier on air quality along a heavily trafficked urban road in Copenhagen

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Road traffic affects the health of urban populations worldwide due to air pollution and noise. Elevated levels of traffic-induced air pollution can be observed in zones directly adjacent to roads causing increased risk of adverse health effects for chronically exposed populations. Barriers effectively attenuate traffic noise and their surfaces can filter air in a way similar to street vegetation and green walls. On the other hand, they also influence the dispersion of traffic emissions and may cause locally increased concentrations of air pollutants. The general benefits of barriers for near-road air quality remain inconclusive.

This study investigates the effect of a planned bio-barrier on dispersion patterns along a heavily trafficked road-section in Copenhagen. It tests the hypothesis whether modifications in barrier morphology, location, and vegetation cover can reduce pollutant concentration levels in the near-road environment. A 3D micro-scale street dispersion model (M2UE) that accounts for urban structures, vegetation, traffic motion, and meteorological conditions was used to investigate various design scenarios. The model consists of a system of Reynolds equations, a two-equation k–ε turbulence model, and the 'advection-diffusion' equation to simulate pollution transport. The computational grid is generated from recent (2014) LiDAR data to closely reflect the actual urban structures including buildings, trees, and shrubs/hedges. This approach allows for place specific design and can utilize local features and conditions in the design rather than inferring design principles derived from stylized urban geometries. A sensitivity analysis was carried out to identify key design parameters with regard to near-road air quality. The results of the analysis feed directly into the design optimization of the bio-barrier and can be evaluated on completion of construction.

How to get living walls into your development to maximise biodiversity and ecosystem services

Veronica Lawrie

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In built up and urban settings space is limited for ecological mitigation. Including living walls as mitigation and enhancement measures to offset impacts on development sites can lead to benefits for biodiversity and can maximise the potential for associated ecosystem services. Global engineering consultancy Atkins has experience of creating living walls within small development sites as well as on high profile flagship projects, such as Birmingham New Street Station. Examples and experience of creating living walls at both scales will be shared. The triggers for creating the living wall habitats will be considered and range from best practice to delivering policy objectives. The contrasting technical specifications of living walls at each scale, both small and large, will be discussed. The biodiversity value of the living walls and their associated ecosystem services will be described. Sustainability and innovation are at the heart of the project examples, which will demonstrate how an ecosystem approach contributes to local resilience, and benefits people, wildlife and the economy.

Role and benefits of vertical gardens in sustainable tourism

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Tourist destinations are rich in natural, historical and cultural resources. These destinations are visited by a large number of tourists for a period of time every year. Tourist sites are under increasing pressure, with new buildings and rising numbers of visitors. In recent years, tourism organizations and administrative bodies have been trying to minimize the unwanted side effects of tourism by adopting sustainable new approaches. Tourism companies have been forced to change their conventional marketing strategies by focusing on environmental concerns. LEED & BREEAM provide international green building assessment certificates for fulfilling certain conditions; increasing green areas near buildings is one of the compulsory conditions of the certificate system. Architects and landscape architects have recently discovered that vertical gardening has the potential for meeting these compulsory conditions. As in other highly regarded tourist cities, designers in Antalya are eager to receive international green building assessment certificates. In response to increasing demand for vertical gardens in Antalya and its vicinity, a number of landscaping companies are installing vertical gardening systems, since Antalya is known as the capital city of tourism in Turkey. This study was carried out in two stages. The first stage consisted of an assessment of the presence of vertical gardens on buildings in Antalya and a survey of satisfaction levels among users, along with the identification of the plants used and an estimation of their value. In the second stage, ecological and economic values of the vertical gardens in Antalya will be assessed using SWOT analysis in relation to an enforcement law which requires 10% of walls to be greened. It is hoped that this study will act as a model and demonstrate the benefits of vertical gardens for other tourist areas.

Performance of green wall treatment of brewery wastewater

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Green walls or living walls are architectural installations comprised of plants growing in soil filled, modular panels that are attached to interior or exterior walls. The objective of this study is to explore the effectiveness of using green walls to pretreat wastewater generated by small to medium sized food and beverage manufacturers. A 1.2 m high green wall was constructed using two 610 mm x 610 mm panels filled with recycled glass media and planted with *Epipremnum aureum*. Brewery wastewater was recirculated through the system under four experimental scenarios: media only; media with biofilm; media with plants; and media with plants and biofilm. Reduction of biochemical oxygen demand (BOD) was at least 75% after 24 hours in all four scenarios. Removal of turbidity, BOD, and total nitrogen was greatest in scenarios involving biofilm with plants. Green walls appear to offer a space and cost efficient method for pre-treating wastewater generated by beverage and food industries.

Social impact assessment of a living wall installed in a hospital

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In recent years, much effort has been devoted by the scientific community to shed light on the multiple ecological and environmental benefits of vertical greening systems. As nowadays the service sector tends to be more environmentally conscious, these systems provide an added ecological and aesthetic value that is highly appreciated by current clients. But, in spite of all the advantages of these technologies, they also have their detractors who uphold diverse issues against their implementation, especially regarding construction and maintenance costs. The reality is that in many cases, a living wall is not installed because of the costs it implies. Therefore, it is important to assess those intangible benefits that increase the value of the living wall and, hence, of the place in which they are installed. Some of them are very difficult to measure, for example, users' perception towards a 'greener' space or the returns obtained by the company because of the publicity related to the living wall.

The main objective of this work is the valuation of those two aspects using as a case study a living wall installed in the 'Sagrado Corazón' Hospital in Seville (Spain). Since its construction in 2012, the hospital has received widespread media attention (interviews in TV and radio programmes, articles in newspapers and blogs, social networks, etc.) because of the living wall. We tried to estimate the investment that the hospital should have made in order to obtain a similar media impact in the case where no living wall had been installed. Taking another approach, we tried to measure hospital users' attitudes towards the presence of such a greening system on the premises and whether it gave more value to the quality of service obtained. For that, several interviews and surveys were performed.

The results showed that even when the cost required to install and maintain the living wall was relatively high, the repercussions and social impact observed helped to recover the investment.

Design and preliminary assessment of a vertical aquaponics system for ornamental purposes

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The term aquaponics refers to combined fish and plant growing systems that may be used for commercial or ornamental purposes. The general principle of aquaponics is that plants act as natural bio-filters of fish water as their growth is supported by fish waste through continuous water recirculation among the two growing systems (aquaculture and hydroponics). Traditional aquaponics systems are based on growing crops in horizontal structures. However, aquaponics systems may also be devised to grow plants in a vertical plane (vertical aquaponics).

Since 2013, the NATURIB research group (University of Seville, Spain) has been carrying out a research project on vertical aquaponics systems. The main goal of the project is to evaluate the capacity of an indoor vertical garden to act as the water biofilter of an ornamental aquarium while preserving its ornamental value. The experimental setup consists of a fish tank filtered with a standard external canister filter (control tank) and a fish tank of similar characteristics but biofiltered by means of a vertical garden (test tank). The main water quality, such as pH, EC, temperature and ammonia content, and fish stocks parameters are being monitored. Plant growth and other ambient conditions are also being monitored.

After the first year of operation, both the vertical garden and the test aquarium are evolving in optimum conditions. Preliminary results indicate that vertical gardens can adequately perform the water bio-filtering function. However, it has to be pointed out that there are still multiple factors and design variables (e.g. relationship between water volume and vertical garden surface, plant species selection, substrate type, fish type and load, etc.) that need to be optimized, as they can have a major impact on water quality and therefore the sustainability of the system.

Vertical Greenery Systems as passive tools for energy and acoustic savings in buildings

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Vertical Greenery Systems (VGS) are Green Infrastructure elements that provide several ecosystem services in urban environments, which are currently highly valued by architects and engineers who broadly include them in their projects. Among others, the main advantages for the building of those systems over traditional solutions are thermal and acoustic regulation, protection of façade materials, visual improvement, and the possibility of food production. As a consequence, at the urban scale they contribute to the improvement of the built environment, the main benefits being the reduction of the heat island effect, the retention of dust and suspended particles of metal contaminants, the support to biodiversity by the reduction of landscape fragmentation and the increase of biomass in the city, retention of carbon dioxide and the positive effects for the mental health of the population through the nature substitution psychological effect. However, some key issues that could affect their operation must be considered, such as the construction system typology, the type of plant species used, climate, and the mechanisms that influence the operation of these green systems as a tool for passive energy savings (shade, cooling, insulation and wind barrier effects).

In order to improve our understanding of the performance of these systems, a long term research project was started within the *GREA Innovació concurrent* research group at the University of Lleida (Spain). Currently, the thermal and acoustic contribution of double-skin Façades and Green Walls are being studied, with interesting preliminary results in both areas. Regarding energy issues, great results have been achieved with energy savings of up to 50% in summer, especially due to the shade effect, both for Green Façades and Green Walls. As for acoustic regulation, the first laboratory studies confirm that Green Walls have great potential as passive sound insulation.

The potential for Living Wall Systems in Nearly Zero Emission Buildings

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The European Union is committed to the minimization of non-renewable resource depletion and environmental pollution in the building sector. This committment is embodied in directives and regulations as well as by methods and tools implemented in ISO and CEN standards. The recast of the European Directive on Energy Performance of Building (EPBD) requires that by 2020 all new buildings should be designed as Nearly Zero Energy Building (NZEB). The energy demands over the building life cycle are often matched to carbon emissions, as highlighted by the International Energy Agency (IEA) Annex 52, Task 40. The importance of this relationship is confirmed by several national regulations where the Nearly (or Net) Zero Emissions Building is a strategic target to be fulfilled. Living Wall Systems (LWS) may be assumed to be a strategic tool for carbon sequestration and for pursuing Nearly Zero Emissions Building targets due to plants and soils. Photosynthesis removes carbon dioxide (CO2) from the atmosphere and stores carbon in plant biomass.

This paper deals with some outcomes related to carbon dioxide accounting developed hand-in-hand with a Living Wall System technological implementation. Consistent with Life Cycle Assessment (LCA) standard, a study was carried out focussed on the contribution of LWS in terms of the amount of exported-imported carbon dioxide. Furthermore some observations on metrics and methodological approach, including allometric equation, are highlighted.

INPS green façade: A pilot project for monitoring the performance of vertical greening in dense urban areas

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In November 2014 the first vertical greening system in the city of Genoa (Italy) was installed on the south façade of a public institution office building built in the 1930s. The building is located in the city centre of Genoa Sestri Ponente, an area characterized by a relatively high population density (13,000 inhabitants per square kilometre). This district, as in most Italian cities, faces many environmental issues, especially due to air pollution. The pilot project was funded by INPS (National Institute of Social Insurance) with the aim of improving environmental quality and energy performance. Performances of vertical greening systems will be qualified and evaluated.

The monitoring activity (developed by the authors) regards the effects of vertical greening in improving air quality, enhancing building envelope performances (i.e. reduction of energy demand for heating and air conditioning) and the evaluation of economic and environmental sustainability. With the aim of evaluating the users' perception of this first green façade in Genoa, a sociological survey was carried out involving local residents and employees working in the building. As demonstrated by several studies, urban green improves citizens' psychological well-being. Nonetheless, the survey conducted before, during, and after the installation of the green façade shows that, with respect to vertical greening, negative effects may prevail in the opinion of (some of) the people interviewed.

Vertical greening from earthenware blocks and their thermal performance

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Vertical greening, green walls or living walls are now becoming a common method of increasing green areas in cities. However, there are still problems of cost and maintenance. In Thailand, imported vertical gardens and systems are popular choices for commercial buildings like shopping centres and condominiums. Felt systems are often used due to their light weight and ease of fixing to old building façades. However, there are problems resulting from the high cost of maintenance and their durability. Many vertical gardens made using a felt system disappeared after a year or less. Simple climbing plants are used even on high rise buildings with access for maintenance. A study was carried out to explore the possibility of using local materials as a support for vertical greening. In Thailand earthenware pots are widely used for plant containers due to their cooling effect and water absorption properties. They are also strong enough to construct a wall. A vertical green block was designed, made of square earthenware plant containers of 15 x 15 x 15 cm, with four holes above and below to drain water down the wall and two side holes for installing on the wall and for an irrigation system. Ground cover plants of different types were grown and observed for six months. Thermal performance was monitored for two months. It was found that earthenware blocks constructed as a 1.80 x 2.10 metre wall can accommodate plants on a vertical surface using one row of automatic drip irrigation every six blocks in height. Plants survived well throughout the experiment and adapted to their vertical situation. The air temperature of the chamber behind the vertical green block was 1-2 degrees Celsius lower from the insulated wall chamber and 2-2.5 degrees Celsius lower than an empty chamber.

Can planted ivy panels be used to improve comfort in the urban realm?

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This paper explores the immediate benefits to building occupants of using planting in an urban context. The design and analysis to be presented focus around the courtyard of a primary school and the potential for ivy panels to be used to improve the inappropriate environmental conditions found in central London. Specifically it will discuss an 'indirect greening system' consisting of a prefabricated system of ivy panels supported on a steel mesh, designed to address the difficulty of defining narrow value ranges for each metric by ensuring planting is grown to a specified range of criteria. To fully appreciate the effects of the planted screens on occupant comfort a multi-pronged approach has been taken, looking at all aspects of occupant comfort as defined by the Chartered Institution of Building Services Engineers. The research is split into five main sections: (1) Shelter (rain attenuation, air movement); (2) Air Quality (particulate removal, pollutant removal); (3) Thermal (temperature, humidity); (4) Visual (illuminance, glare); and (5) Acoustic (reverberation time, distortion, absorption).

The multifaceted approach is intended to give a more complete account of the benefits of using vegetation in place of more traditional solar or acoustic façade treatments. While mechanical systems, or highly engineered façade systems, are clearly capable of achieving higher levels of comfort in each given category, this research will explore whether the combined effects from vegetation may be more beneficial overall compared to a mix of more traditional systems.

It is hoped that a detailed understanding of the micro-climatic effects of planting can lead to planting being seen as part of the building services, subsequently reducing the need for mechanical services. It therefore seeks to incentivise building owners and occupiers, rather than city authorities.

Particulate pollution mitigation using living walls: an ongoing study

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The value of living walls in capturing particulate matter and their potential to reduce urban traffic-generated pollution has received scant attention. Likewise, there is little data on the optimal species composition for particulate capture. This study will employ an experimentally manipulated modular living wall system to explore the reduction of particulate pollution from traffic-generated sources. The overall approach will be to explore the optimum species characteristics and other influential factors required to trap particulates. A wide range of plant morphological types will be selected as experimental species (e.g. evergreen conifers, 'grasslike' species, small-leaved and large-leaved deciduous and evergreen species). Sampling will be carried out in two different seasons (June-September and December-March). Particulate capture on leaves will be quantified using an Environmental Scanning Electron Microscope (ESEM) and image software with reference to PM10, PM2.5 and PM0.1. Total particulate capture for a plant will be calculated using the Leaf Area Index. Inter-species variation in particulate capture on leaves will be evaluated using GLM. Leaf surface characteristics, such as number of stomata, number of trichomes, length of trichomes, density of ridges and density of hair, will be quantified using the ESEM; any positive correlation between leaf surface characteristics and particulate capture will be identified using GLM. The elemental composition of the captured particulates will be ascertained via Energy Dispersive X-ray analysis using the ESEM. Any seasonal variation in capture efficiency will be identified using GLM. Cumulative capture data will be plotted against daily precipitation and daily wind speed to identify the impact of rainfall and wind speed on particulate capture. The optimal species composition for particulate capture by living wall systems will be explored by changing the combination of plants, planting designs and micro-topographical variations.

Indoor plants and living walls: air quality and rhizosphere interactions

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Volatile organic chemicals (VOCs) in the indoor environment are known to elicit various negative health impacts in man. Numerous plant species have the capacity to remove VOCs from the environment, a process termed phytoremediation. Microbes in the root zone (rhizosphere) of plants are considered the principal site of VOC degradation and can account for up to two-thirds of the total VOC removed from the environment. Significantly, different plants appear to process specific VOCs more effectively than others, with some plants exhibiting no ability to remove VOCs from their environment. Such functional variation between plants is thought to be due to differences in the microbiome of their rhizosphere. In this study, various plant species will be challenged with a mixture of common VOCs including benzene, toluene, xylene and n-hexane in static test chambers. The reduction in specific VOC concentration in each test chamber will be evaluated after 24 hours using gas chromatography and mass spectroscopy. The role of the rhizosphere microbiome in VOC detoxification will be determined using state of the art next generation sequencing-driven metagenomic techniques. Rhizosphere DNA will be extracted using the QIAamp Fast DNA Stool Kit and variable regions 3 and 4 in bacteria (V3 / V4), and intergenic transcribed spacer units 1 and 2 (ITS1 / 2) in fungi will be amplified by polymerase chain reaction (PCR). The resulting amplicons will be sequenced using the MiSeq PE250 system (Illumina) to generate sequence data from the entire bacterial and fungal community present. Following sequencing, a range of bioinformatic techniques will be utilised to cluster and map the resulting sequencing data and accurately determine the species present within each of the rhizosphere samples. Relationships between the presence and absence of specific microbiome members and VOC detoxification efficacy will be determined using appropriate statistical models. Results from this study will enhance our understanding of the role of the rhizosphere microbiome in VOC detoxification and will ultimately assist in the optimisation of phytoremediation systems for specific environments.

Nathan Cook | MMA Architectural Systems, UK

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Nathan's presentation will look at the specific design, installation and maintenance requirements for climbing plant green wall systems. He will give an overview of the different substrates that climbing systems can be fixed to – including bricks, blocks, Metsec and other composite structures – and then outline the key installation requirements. This will include a look at typical project timescales and an assessment of site requirements, such as the amount of material required, ensuring adequate spacing between the green wall and the façade, loading capabilities, designing around openings and features and general planting considerations. Finally, Nathan will provide guidance on ongoing maintenance – outlining the frequency of visits, access requirements and the need for effective irrigation to ensure the long-term health of the green wall.

Having graduated with an honours degree in Civil Engineering and Architecture, Nathan joined MMA Architectural Systems in 2012 and is now a Senior Project Manager at the company. Nathan supports customers with all aspects of green walls – from initial design advice to installation and maintenance. MMA is the sole UK agent for the Jakob ranges of stainless steel ropes, rods and wire mesh systems, the products having been proven in a wide range of projects of varying shape, scope and complexity. The company's Green Wall Solutions range has been developed to meet the needs of architects, developers, contractors and building managers, providing a host of design, installation cost and maintenance benefits.

Mark Laurence | Vertology, UK

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Mark's presentation will focus on the advantages of using a hydroponic living wall system: they require less maintenance than compost-based systems, nutrients are supplied in a precise and controlled manner, the water reserves last longer should supplies to the wall be interrupted, and overall the system dynamics are more stable. Vertology uses its own unique and patent-pending hydroponic modular system for living walls – Viridiwall. Designed and developed by Mark, it is a continuation of his pioneering work already established with the Biowall system. Viridiwall takes things one step further in terms of aesthetics,

refined performance, flexibility and reliability. Based upon years of trialling and experimentation, the Viridiwall panel builds on all the best qualities of hydroponics to provide just the right balance of moisture and air within the mineral fibre, stimulating good root penetration into the medium for plants to give optimal performance.

Mark Laurence is a pioneer in the world of sustainable landscapes and vertical greening. A landscape designer and practicing arborist for more than 30 years, in 2007 he conceived of and co-founded Biotecture, a UK based green wall company. There he co-developed and patented the Biowall System, a modular hydroponic vertical greening system now proven as a robust, market-leading product, in use across Europe, the UAE and the USA. Since then he has gone on to set up Vertology, to further his own specific systems and vision of vertical greening. He has extensive plant knowledge, design flair and experience in applying plants across a vertical canvas and in assessing suitable plants for different climate zones, including Chicago, Norway, Spain, Dubai and Abu Dhabi. Current work includes new trials in Saudi Arabia (focusing on evaporative cooling benefits) and the development of new systems to optimise particulate capture for air pollution, furthering his earlier work with Transport for London.

Steve McIntyre | ANS Global, UK

steve.mcintyre@ans.global

Steve's presentation will focus on the importance of installing and maintaining a living wall correctly in order to ensure that the long term benefits of sustainability are fully realised. He will focus on substrates and the importance of water management to ensure the healthy development of a living wall.

Steve McIntyre is Sales Executive for ANS Global. Having studied plant propagation and developed his own nursery business, in 2006 he started looking at ways of developing green roofs and living walls. By the end of 2007 the company was in a position to install its first living wall. The research did not stop there, and they now have in excess of 300 living walls installed globally. The pre-grown ANS modular system means fast installation and almost instant results. The company is passionate about living walls and is committed to sustainability and longevity.

Tijana Blanusa | Royal Horticultural Society, UK
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Various forms of green infrastructure are being increasingly recognised for their ability to provide a range of ecosystem services, including regulation of temperatures, insulation of buildings, noise and pollution abatement, regulation of water cycling and mitigation of intense rainfall, to name just a few. Tijana's work starts from the premise that differences in plant structure and function should lead to differences in plants' capacity to deliver various ecosystem services; she is therefore studying a range of plant species (and cultivars) with contrasting leaf and canopy attributes and their provision of individual as well as multiple ecosystem services. To date this research has shown that plant species (and cultivars of the same species) can differ greatly in their ability to cool their own leaves as well as the surfaces around them. For example, species (which could be used in green roof and wall applications) with greater leaf areas and rates of water loss, which were light in colour and/or had leaf hairs performed best in terms of reducing heat transfer into the substrate as well as aerial temperatures in the close proximity. Some of these characteristics (hairiness, larger canopy) can also be correlated with a superior ability of species to capture particle pollutants. Additionally, species with inherently greater rates of water loss also enabled better restoration of soil's water-holding capacity, thus potentially improving the ability of plant-soil systems to hold excess rainwater. Certainly, the suitability of a plant for a particular environment ('plants for places'), its ornamental appeal and its cost will remain the drivers of plant choice for green infrastructure. However, Tijana will argue that we also need to understand the differences between species in terms of ecosystem services delivery, and take them into account when choosing plants for our green spaces in order to improve the benefits we reap from them.

Dr Tijana Blanusa is a Senior Horticultural Scientist with the Royal Horticultural Society (RHS). Her research interests are in understanding the role of small (urban) green spaces (particularly plants in domestic gardens) in providing multiple ecosystem services. She currently runs several projects investigating the contribution of green roofs, green walls, garden hedges and other forms of green infrastructure to the moderation of air temperatures, rainwater capture and aerial pollutants. Her post is based at the University of Reading, within the School of Agriculture, Policy and Development; she collaborates with colleagues from a number of other schools and external organisations.

Shelley Mosco | University of Greenwich, UK

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When selecting a place to grow plants there are two questions that first need to be answered: will they grow, and will they grow well? Shelley's talk will explore which plants grow well in living walls, and why. It will examine the complexities of choosing plants for modular living wall systems, as well as vertical microclimates and considerations of climate change.

Shelley Mosco is a Research Assistant in the Department of Architecture and Landscape at the University of Greenwich where she is also Senior Lecturer in landscape design and GIS (Geographical Information Systems) for Landscape Planning. Shelley is a landscape architect and director of her own private practice, specialising in green and living wall design. She has been involved in projects such as the UK's tallest living wall, recently installed at the University of Newcastle's Science Central; Network Rail's Birmingham New Street Station and Transport for London's Puddle Dock living wall which was used as a study for air pollution mitigation. Her plant knowledge and growing expertise of Europe's living wall system leaders puts her at the forefront of this emerging technology.

Kevin Hobbs | Hillier Nurseries, UK

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Much is known about the life enhancing properties of plants, yet there is limited and slow uptake in the retail and commercial market for living walls and other innovative greening solutions. Nature has always allowed various plants to grow and even flourish in cities, often in challenging situations, and Flora Fanatica has harnessed that approach in order to develop a living wall system that incorporates climbing plants and engineering in an innovative way. Kevin's talk will focus on identifying and sourcing appropriate plants for living walls, the great range of climbing plants available and some of their specialist properties, new ways of using climbers to provide instant appeal, and his ideas for retrospective greening in our towns and cities. Research conducted by Portsmouth University on the Flora Fanatica system has identified the plants that can contribute to rain water attenuation, thereby fitting neatly into a sustainable urban drainage plan. By increasing the variety of different types of plants and the different ways of including them in living walls, we can readily increase and help sustain the

biodiversity corridors. Kevin will suggest some hidden gems that could excite the senses and attract the bees and insects.

Kevin Hobbs is a horticulturist with extensive knowledge of plants, their attributes, physiology and benefits. He is Nursery Director at Hillier Nurseries, the UK's leading grower of hardy nursery stock, and co-founder of Flora Fanatica Ltd. Kevin draws upon 30 years of personal experience as well as 150 years of Hillier Nurseries expertise. Together with The ACO Group, Flora Fanatica and Hillier are developing innovative Urban Greening Technologies that include irrigation / rain water attenuation for Green Walls.

Armando Raish | Treebox Ltd, UK
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As global population continues to grow and more of us are forced to live in closer proximity to one another, the need for green infrastructure in our towns and cities is higher than ever before. Smart cities are often seen as technologically advanced habitats with complex networks of services and infrastructure designed to provide us with conveniences and comforts we have come to expect. However, can our modern lifestyle come at the expense of our basic human needs; needs that we tend to take for granted but are fundamental to our health and wellbeing? The challenge to return natural processes in all its forms into our urban environments, whilst competing with habitable space, has demanded a more innovative approach to the problem. Armando will explore how 'living' façades and roofs are a direct response to this challenge. This relatively recent trend utilises the otherwise overlooked surface area of our building envelopes, by understanding the environmental and financial benefits they provide. He will discuss how we can monetise the value of ecosystem services and their worth, whilst asking 'Is nature in cities a luxury or a necessity?'

Treebox Ltd was established in 2009 by Armando Raish, whose professional credentials and experience includes over 15 years in architectural design along with landscape design and construction in Australia. Always motivated to discover sustainable answers to meet our modern lifestyle choices, Treebox was instigated to become a vehicle for positive change in our communities and cities by bringing forth practical and aesthetic greening solutions. Armando was inspired by the passive benefits that living walls offered our cities, including increased thermal insulation, noise reduction and improved air quality to name a few. Over five years on Armando has continued to innovate and develop solutions that make living walls a viable option, from passive irrigation systems to Bio-filtration. He has now consulted and assisted in delivering over 100 living wall projects across the UK and Europe. Armando is currently sharing his knowledge and experience with likeminded professionals by conducting workshops and training courses throughout Europe.

Sarah Milliken | University of Greenwich, UK
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The economic valuation of ecosystem services should be a potent decision-making tool for local authorities. Ecosystem services play a critical role in local economies, and well-designed and well-managed urban landscapes can even underpin sustainable economic growth. However, as vital as nature is to our communities, if it is poorly planned and piecemeal, then the benefits that it could potentially deliver will not be realised. Built environment professionals also need to understand the importance of integrating economic objectives into project development: only by appreciating the benefits that nature provides, and by understanding the value of these benefits, can we move towards creating cities that are truly sustainable – economically, environmentally and socially. Sarah will discuss the various toolkits that are available for valuing ecosystem services.

Dr Sarah Milliken is a Research Assistant in the Department of Architecture and Landscape at the University of Greenwich. Originally trained as an archaeologist, Sarah has taught at various universities in the UK, Ireland and Italy. A keen interest in environmental issues and a desire to be able to actively address them, recently led her to undertake postgraduate qualifications in landscape architecture and urban sustainability. Her current research focuses on how the economic and non-monetary evaluation of ecosystem services can be integrated into the discourse and praxis of landscape planning and design.

Richard Sabin | Biotecture Ltd, UK
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If we can turn the dial of perception of Green Infrastructure from Cost to Value in the minds of clients, specifiers and end users, then we will be able to fundamentally improve our urban landscapes. To maximise its potential benefits, green infrastructure needs to firstly be considered at a strategic level, and secondly integrated at an early stage of development. Once we are doing this, phrases like eco-system services, networks of green spaces and biophilic design will start to have real meaning. The aim of this workshop presentation will be to provide examples and encouragement that the dial can and is turning, and to empower us to all become more knowledgeable advocates of the benefits of Green Infrastructure.

Richard Sabin is Managing Director of Biotecture Ltd. He has over 25 years' experience in the construction industry, and an abiding interest in the environment and in man's influence on it, particularly in the urban building context. For several years Richard ran his own environmental and sustainable building consultancy. In 2007 he co-founded Biotecture Ltd, with the vision of bringing a truly robust living wall system to the market. In doing so he realised many of his ambitions for improving the quality of the urban environment. The company has become one of the foremost providers of external and internal living wall systems nationally and internationally, and it continues its mission in research and thought leadership. In 2014 Richard co-founded Living Green City, a Green Infastructure Company. He is also a Director of the Synergetic Foundation which looks to promote and advocate any contributions that move the biosphere towards a healthier future.

George Irwin | Green Living Technologies, USA
george@agreenroof.com

Five times, ten times or twenty times your average yields! These are the production rates of a well-planned vertical farm maximizing energy and water while controlling the key environmental variables for predicted outcomes. Don't confuse this vertical farm with leafy green hydroponics: this discussion will demonstrate the use of organic techniques derived from traditional farming to grow higher value crops and herbs. Our food supply is becoming increasingly stressed and we need to grow food in greater quantity; however, quality and nutritional value is of critical importance. The vertical farm techniques discussed here will provide an insight on growing vertically using biological activity between plants and bacteria and the benefits of humic acid. This technique contributes to nutrient quality and increased brix levels while utilizing existing building structures within urban environments. Topics will include configuration, lighting, environmental controls, sustainable full circle biological system applications and water conservation with dialogue intertwined with additional educational and economic development.

George Irwin is the founder and President of Green Living Technologies International LLC (GLTi). He is also a global pioneer in vertical agriculture with a focus on education and training. A published author and the featured 'Green Wall Editor', George is also a leading resource and authority for green wall and roof technologies around the world. Prior to founding GLTi, George was a landscape contractor for over two decades. He holds a degree in education and maintains his passion for out-of-the-box learning, combining his love for the environment and zest for learning into a growing global business. George personally oversees all green wall and roof education, integrating state-of-the-art technology and ideas into a continuously evolving educational and training curriculum. Annually, he teaches hundreds of new green technology experts in green roof and living wall manufacturing, installation, growth, and maintenance. His mission is to help create sustainable solutions to the challenges of food insecurity and the dearth of job opportunities for at-risk youth in inner cities through vertical farming.

Benz Kotzen | University of Greenwich, UK
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The appetite for living walls is growing. Government organisations, local authorities, business as well as local people are becoming used to and appreciative of the environmental benefits that these green infrastructure projects can bring. Development in living wall technology and use scenarios is changing rapidly and living walls are now starting to be used as much indoors as they are used externally. One application that has yet to be fully explored is the use of living walls to grow produce both inside as well as outside buildings. There is a groundswell in growing food locally, especially in urban areas. This drive is based largely on improving family and community health and well-being, but also bring benefits in food security, reductions in food miles and CO2 emissions. But growing food horizontally in soil uses up space that may not be available in cities. Thus vertical growing is on the increase. This workshop investigates living walls for growing food and in particular integrating living walls into aquaponics production.

Dr Benz Kotzen is a Chartered Landscape Architect, teacher, designer and researcher. He is a senior lecturer, Post Graduate Landscape Course Coordinator and Sustainable Landscapes and Environmental Research Group Leader at the University of Greenwich. The focus of the group is on urban green infrastructure; green roofs, living walls, urban agriculture and aquaponics. The focus of the research extends across the globe into dryland and arid areas with particular regard to water issues and restoration as well as into food production in developing countries.

Tomaz Cufer | Humko Bled, Slovenia
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Tomaz will discuss his vision for the future for vertical farming and share his many years of experience growing edible produce in modular vertical systems. He will demonstrate the connection of fertiliser in mineral substrates to vegetables. Tomaz will also give a 'sneak preview' of his latest development of a complete system for growing and maintaining vertical gardens by online control, connected to meteosat data, fertiliser calculator and web service protocol.

Tomaz Cufer was Slovenia's youngest entrepreneur when he began a vermiculture business for growing edible and ornamental plants while employed as Head Gardener in Vila Bled, former President Tito's summer residence. He eventually developed a thriving private business – Humko Bled, now producing over fifty products consisting of compost, growing media and organic fertilizer products, including vermichar and biochar, along with their own living wall system. Fifteen years ago Tomaz pioneered their first living wall programme for greening highways. This developed into a vertical modular system, for growing edible plants and can also be used as a decorative architectural façade. His latest innovation is a low budget multi-layer system particularly suited for growing plants in extreme temperatures, featuring double irrigation and a defrosting system.