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Naložba v vašo prihodnost
OPERACIJO DELNO FINANCIRA EVROPSKA UNIJA
Evropski socialni sklad

Cities of the Future

Ljubljana, 2014

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Content

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Foreword

Rapidly growing urbanization world-wide, combined with climate extremes (droughts, extreme heat, and extreme rain events and floods) calls for an urgent change in planning of our cities one that supports management of natural resources across multiple sectors, scales and disciplines. This requires a certain level of decentralization of urban infrastructure, leading to the application of innovative technologies or combination of technologies for integrated management of water, food and energy within the city.

This workshop is about the latest developments, projects, and case studies in this area. It is based on the results of the following projects and activities.

The Blue Green Dream (BGD) project is supported by the European Institute of Technology's programme Climate KIC. BGD promotes a new paradigm for the efficient planning and management of the urban environment: one that maximizes ecosystem services minimizes environmental footprint and increases cities' adaptive capacity to changing climate, demographic and socio-economic conditions. The project aims to enhance the synergy of urban blue (water) and green (vegetation, energy efficiency) systems and provide effective, multifunctional Blue Green Solutions (BGS) to support urban adaptation to future climatic changes.

Extensive long-term research on sustainable systems has been conducted by the Ecological Engineering Group of Zurich University of Applied Sciences. It includes sustainable systems for wastewater treatment and food production (Aquaponic) and their significance for the development of Urban Agriculture, Building Integrated Food production and Zero emission Buildings.

Innovative household centred approaches to water and wastewater management in cities, *i.e.* concepts for zero outflow and closed loop systems for water, substances in wastewater and energy are in development. They can be part of an integrated urban substance flow management, which is both environmentally acceptable, and resource and cost efficient. Their challenge is to be applicable in industrialised as well as in developing countries. The concepts have been and are being tested in various settings and practised by various initiatives.

Community led initiatives like Transition Towns offer a well-established network of various groups of citizens working towards improvement of local economies, creating livelihood, sustainable urban solutions, and green jobs, whilst also seeking collaboration with governments, businesses and universities. Such collaboration is a necessity for transforming our cities into low-carbon economies with zero ecological footprint.

Trends in sustainable design of future cities

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Abstract

This paper presents innovative methods of increasing resilience of urban areas to the adverse effects of natural disasters caused by climate changes and extreme weather conditions such as heat and cold waves, heavy storm and prolonged droughts, combined with manmade problems such as air pollution, noise and increasing urbanisation. They call for a new paradigm for the efficient planning and management of the urban environment: one that maximizes ecosystem services, minimizes environmental footprint and increase cities' adaptive capacity to changing climate, demographic and socio-economic conditions. The new paradigm calls for a rethink in existing ways of planning, designing, constructing, operating and maintaining urban water systems (blue assets) and urban vegetated areas (green assets), not as separate systems as is the case today, but in combination.

This paper (extended abstract) presents the methodology applied in the Blue Green Dream (BGD) project for tackling the above issues by developing and testing innovative methods of urban planning and asset management in integrated fashion and how the BG solutions implemented are tested, improved and their performance indicators quantified by the "next generation's" Blue Green Integrated Modelling System (BG IMS). The initial results obtained in both research projects (full scale plus MSc and PhD projects) and initial demo projects (Berlin, London, Paris and Rotterdam) as well as in full scale developments in which the BGD concept was implemented are presented. These results illustrate the "framework" of the future urban planning methodology developed to realise the BGD paradigm. This state-of-the-art planning and modelling methodology is demonstrated and the gaps in knowledge and limitations plus improvements required of the existing models to effect a step-change in urban planning are presented.

Key words: innovative planning, resilient cities, integrated, ecosystem optimisation

1 Introduction

This paper describes a new paradigm which conceives the planning, design, construction, operation and maintenance of urban water systems (blue) and urban vegetated areas (green assets) not separately but in combination, placing emphasis on their mutual interactions. The Blue Green Dream (BGD) project introduced in this paper enhances the synergy of urban BG systems through the use implementation and use of multifunctional Blue Green Solutions (BGS). The paper presents the project concept and deliverables including an Integrated Modelling System (BGD IMS). Additionally, it highlights the potential for collaboration with and arising from the BGD project.

The BGD project will fill the knowledge gaps and develop refined modules for key urban infrastructure related processes in order to understand and model the interaction of blue and green assets. The modules utilise existing state-of-the-art models whilst also offering sharper definition of the fine scale boundary conditions and improved modelling of the interactions of plant, soil and microclimates and moreover, the interactions of BG assets with models of BIM (Building Information Management). The tools are applicable for the design of new assets and urban areas, as well as for retrofitting of existing ones. The test beds are in Berlin, London Paris and Rotterdam with 18 core project partners and support organisations/affiliates: the national clusters are based in France, Germany, the Netherlands and the UK.

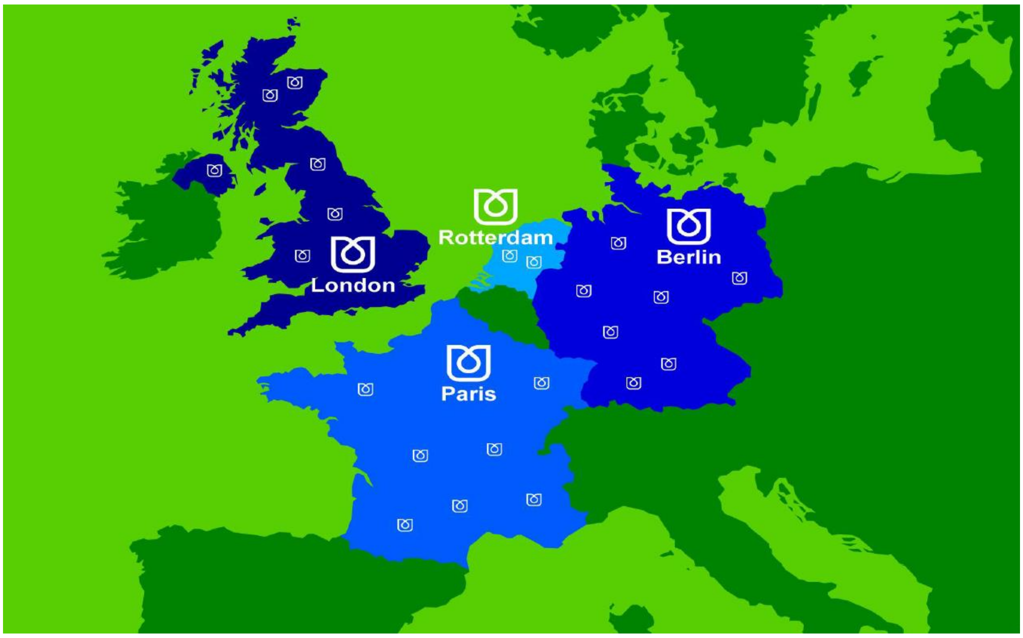

Figure 1: The Blue Green Dream core countries and demo sites

The role and collaboration mechanism of the BGD network is presented in the paper. Additionally the paperpresents the concept of an open access modeling system, details of modules and data structure, experimental and full scale research facilities as well as initial simulation results, supported by e-learning modules. The international science conference *Reporting for Sustainability*, (Bečići, 7th–10th of May 2013) has served as a platform for exploring the potential for synergy between the BGD members and the network of Regional BGD centres, each of which has a focal point for each member country (such as the one in Slovenia) for the planning of joint actions, deliverables and implementation mechanisms.

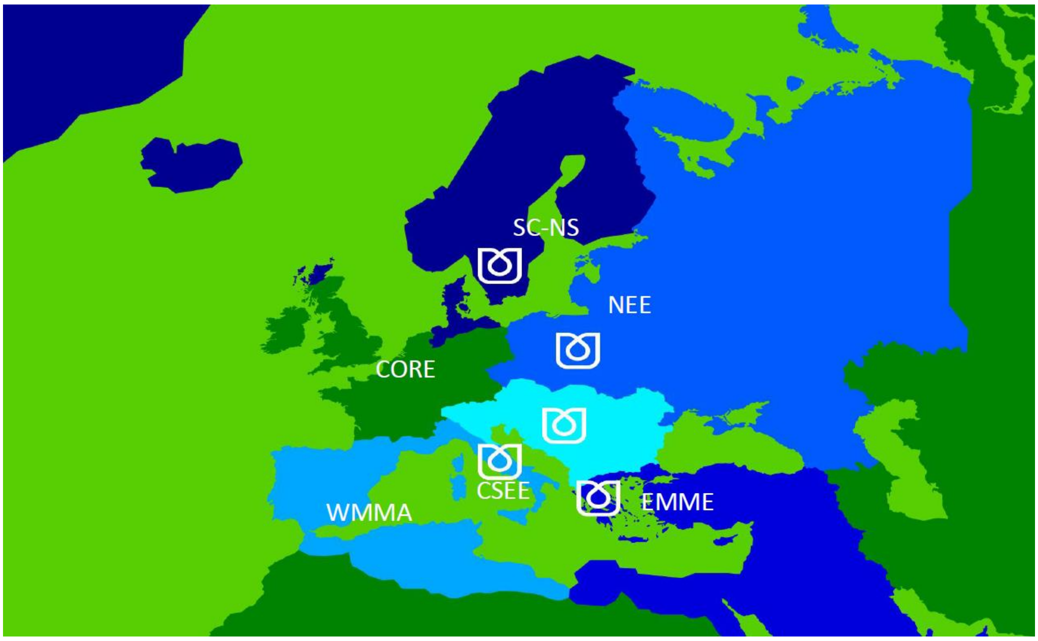

Figure 2: The Blue Green Dreams European regional centres

2 Part 1. Blue Green Dream Paradigms for Innovative City Planning

The Blue Green Dream (BGD), http://bgd.org.uk, project offers new technologies (BG Solutions - BGS) for efficient planning and management of the urban environment: to maximize ecosystem services, minimize negative environmental impacts and increase cities' capacity to cope with changing climate, extreme weather conditions, demographic and socio-economic conditions.

The BGD Centre for CSEE (Central and South Eastern Europe) is located in Belgrade, Serbia and has focal points in Italy, Switzerland, Austria, Slovakia, Hungary, Romania, Bulgaria, and in all former ex-Yugoslavia republics. Members include the BGD project's principal coordinator and a group of companies and world leading experts. It has been created to bolster and enhance the relevant national ministries capacity to introduce BG technology and to design and build BG settlements (smart sustainable cities) in member countries. Additionally, it will work with local academic and professional communities to assist them in mastering BGD technologies and facilitate their implementation in the region.

2.1 The main products

Rapid urbanization (often uncontrolled) and the adverse impacts of climate change and the variability of its extremes pose severe threats to urban ecosystem services and functions, threatening human health and presenting grave limiting factors for national economic development. The major issues (*inter alia*) are as follows: a) Urban creep (for example London loses 2.5 Hyde Park equivalents of green space annually); b) Reduced availability of water resources for potable and industrial purposes, food and energy; c) Poor drainage, floods and droughts; d) Pollution of water bodies, reduced air quality, increased noise; e) Poor energy efficiency of buildings and urban heat islands, poor performance of ecosystems.

Blue Green Solutions enhance the synergy of urban blue (urban water infrastructure) and urban vegetated areas (green systems) by providing multiple benefits to services and functions of urban ecosystems. They encompass technologies developed previously, such as SUDS (Sustainable Urban Drainage System (known as best management practices (BMPs) in the USA) and WSUD (Water Sensitive Urban Design) but also go beyond them. They provide effective, multifunctional support to urban adaptation to future climate change and variation of climate extremes.

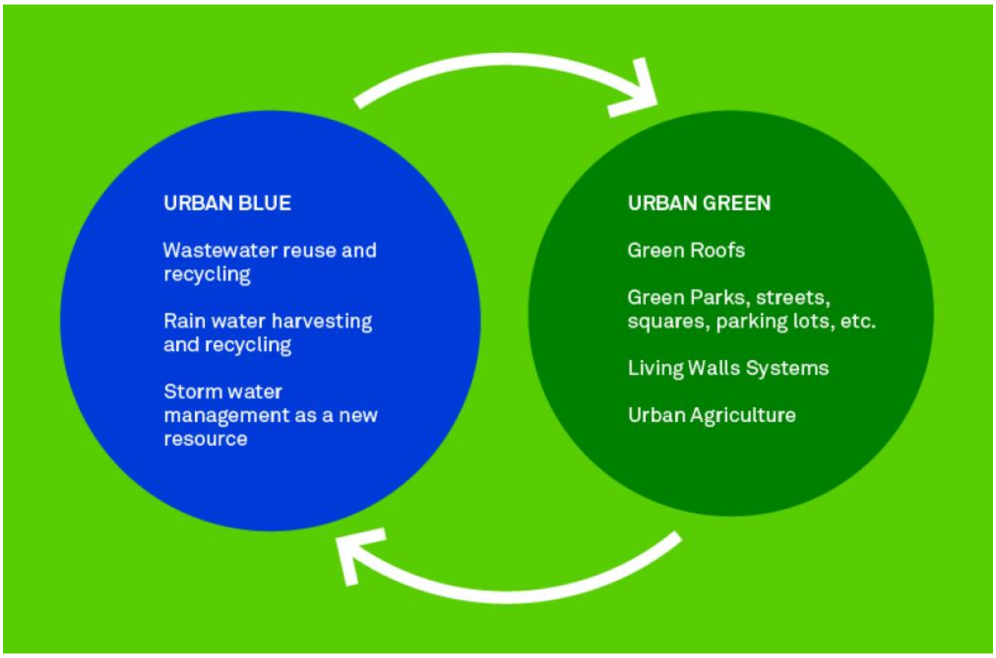

Figure 3: Urban green and urban blue

The key issues creating the need for BG solutions are presented in Fig 4. Inter alia the multiple benefits of the implementation of BG solutions include: reduced pressure on natural water resources, increased / enhanced resilience to drought and flood risk, reduced water, air and noise pollution, mitigation of extreme heat and urban heat island effects, reduced energy requirements (for heating and cooling of buildings), sustainable urban food production and enhancement of amenities, biodiversity and quality of life (urban health). Additionally, they have significant socio-economic benefits, such as: job creation and reduction in antisocial behaviour and crime. BG solutions are thus considered essential in the planning of both new urban development and retrofitting of the existing urban fabric.

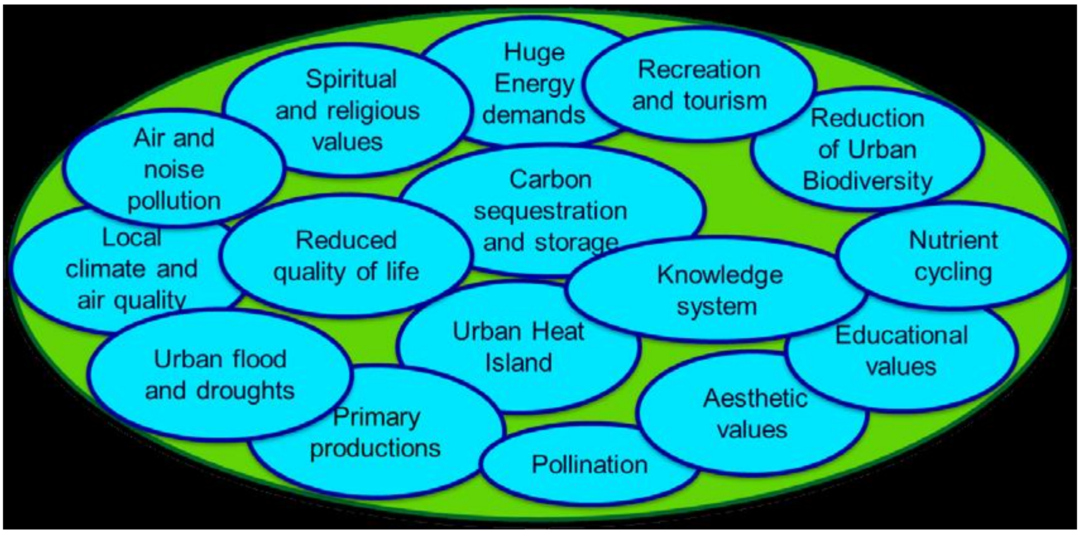

Figure 4: Issues creating the need for an integrated BG solution

The BGD project has proposed to the relevant ministries collaborations and initiatives based around the following two major groups of activities:

a. ***Innovative strategic planning*** at the central, regional and local government levels for development of national policy and drafting legal documents on innovative methods of planning, design, construction, maintenance and management of urban areas based on the BGD philosophy in order to achieve long term sustainability of the cities planned.
b. ***Innovative spatial/urban planning*** of new cities (new developments) and retrofitting of the existing ones. Innovative planning is based on integrated planning and optimized modeling of interactions of urban functions and eco system services.

Design of sustainable and smart/resilient cities based on the Blue Green Solutions is becoming a global trend and it is very likely that all countries and cities in the world will adopt this approach.

2.2 The major differences between BGS and the conventional design

Standard urban planning is usually done by different specialists without analysing mutual interactions; typically only a few interactions between different project components are considered. Under the BGD paradigm, all possible interactions between an urban settlement's components are modelled and the "best possible" (optimized) solution proposed for the final design. This is done through an active "integrated design and modelling" process characterized by:

- Interactions between urban solutions/ecosystem services, greenery, water cycle, renewables, efficient building, biodiversity and pollution streams are systematically analysed (modelled with the most recent software systems);
- Improvement of each above component's efficiency is simulated for different design and operating conditions;
- Interactions between the above components are quantified (technical and financial). Quantification is conducted both for the standard operating conditions as well as for the extreme natural events and visualised in an easy to understand form.
- Quantified interactions and benefits are transformed into proposals/instructions that will inform the design process and aid the achievement of sustainability and efficiency goals.

The major benefits of BG Solutions

- Demands of water resources are managed (locally harvested and recycled), hence saved and used more efficiently;
- Greenery is selected and located to minimise water use, improve outdoor air quality, save energy, reduce urban heat island effects and improve health, aesthetic values and biodiversity;
- Buildings, streets and public spaces are designed to capitalise upon the benefits of greenery, recycled water management, renewable energy, reduced noise, water and air pollution, thus rendering the target area cheaper to maintain and healthier and more comfortable for people to live in;
- This approach secures lower overall capital and operational cost, including urban infrastructure for water, greenery and energy (insulation for buildings).
- All urban components are designed to mitigate the effects of extreme anthropogenic impacts and natural disasters, climate change and extreme weather variability.
- Finally, the BG Solutions based developments are cheaper to build, utilize and maintain. They are significantly more sustainable and efficient and much more resilient to climate change, extreme weather and the effects of natural disasters. Such

developments are more amenable to both human beings and the environment and have higher market value.

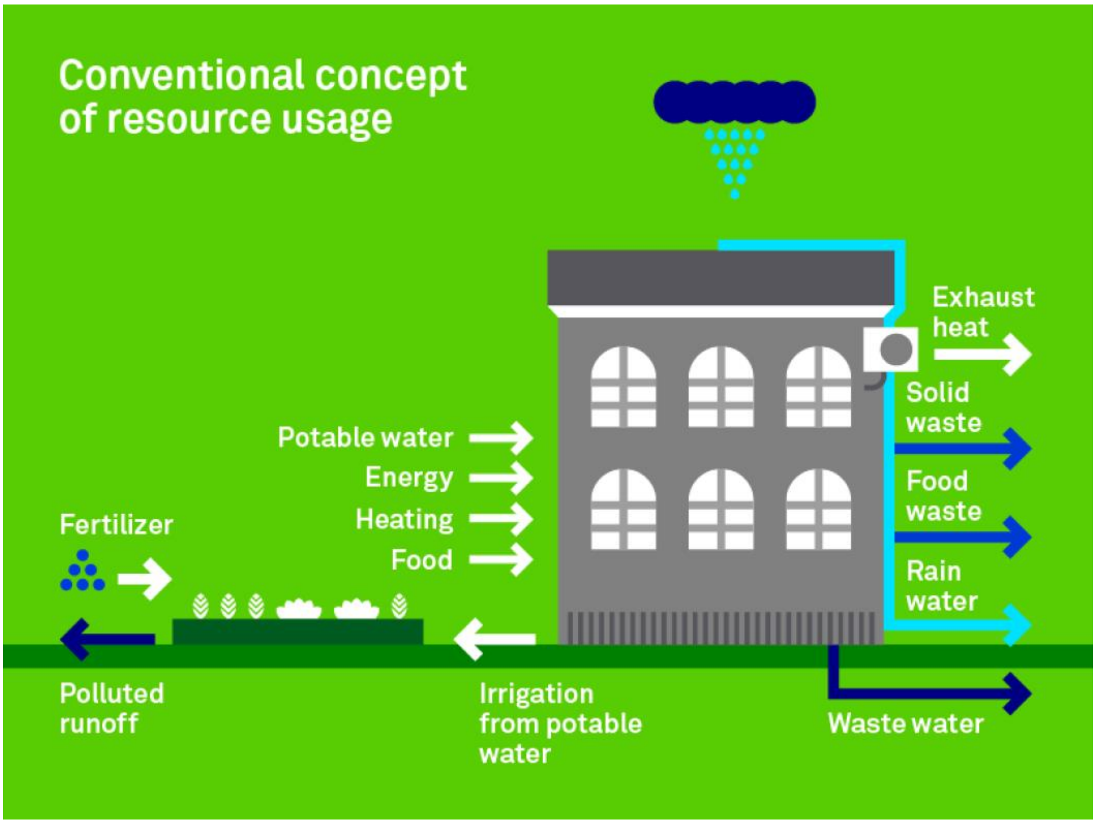

Figure 5: Conventional concept of resource usage

2.3 Tools and Implementation Mechanisms

The physical processes for which individual models will be developed are presented in Figure 6.

Inter alia, the processes involve: water balance and recycling resources, nutrient and pollution migration, pollution of water, urban flooding, urban heat islands, energy efficiency, water and air quality, noise, biodiversity and urban amenities. It also includes the issues of urban agriculture, governance and stakeholders' involvement regarding funding mechanisms.

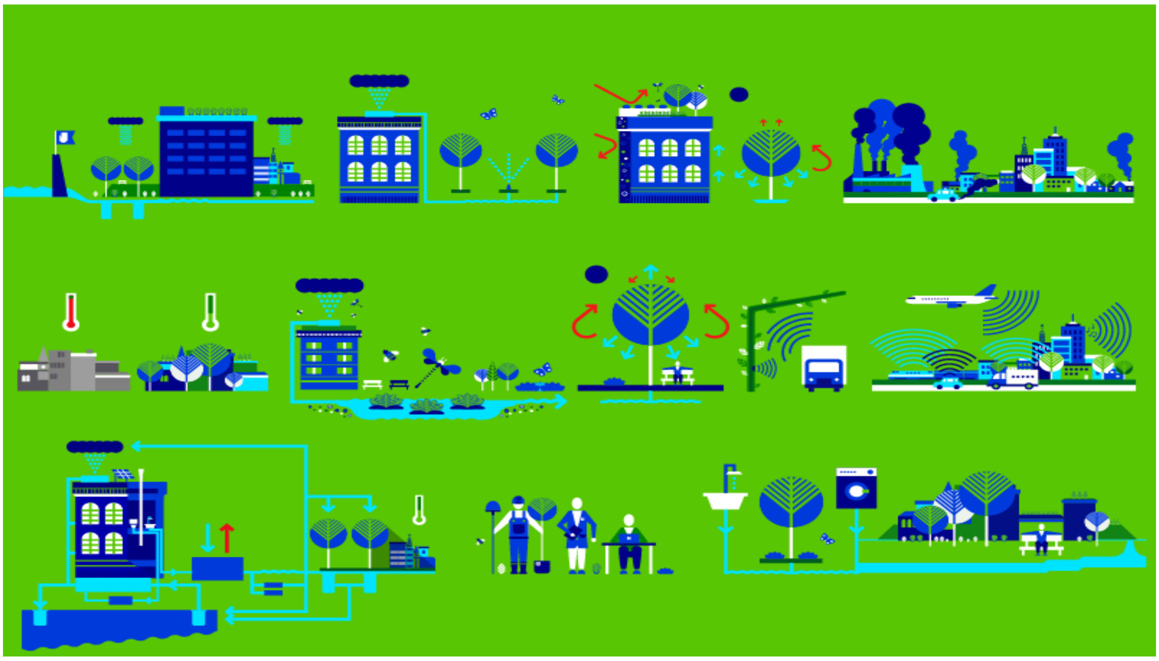

Figure 6: Physical processes and socio-economical interactions addressed in the BGD project

These processes are covered by applied research through MSc and PhD theses run at both core partner universities (Imperial College London, ENPC (Ecole National des Ponts et Chausses), Paris TU Delft and TU Berlin) and at the universities that are joining the network of regional centres and national focal points. This research is then combined with the expertise of industrial partners for development of a range of innovative modelling and planning tools based on 3 levels of complexity for three levels of spatial planning as follows:

a. The initial level of urban / spatial planning.

Used mainly in the initial (master planning) phase of design for rapid assessment of BG Solution options and initial assessment of their performance based on the "best available" solutions from literature (without detailed modelling of performance). This encompasses the Adaptation Support Tool (AST), which is being developed by the Dutch BGD partners, presented in Fig 7.

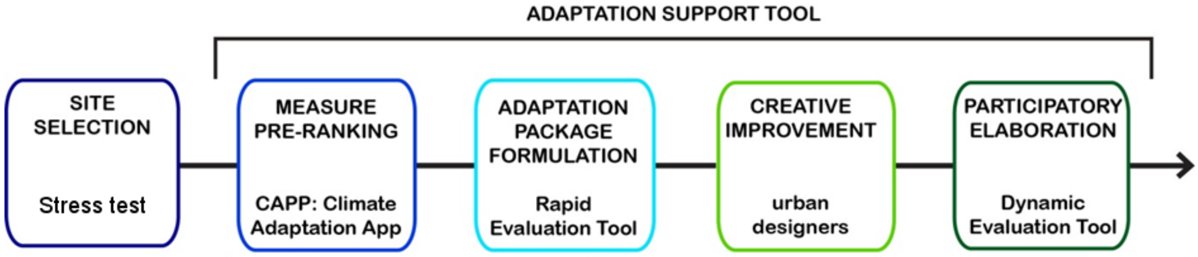

Figure 7: Concept of the AST Adaptation support tool

b. The intermediate level

This level is centred on the UWOT system for: “simulating interactions between urban water and green components”. This level includes models which are in the public domain such as SWMM. **UWOT** is a bottom up (micro-component based) urban water cycle model, which simulates demand at multiple time steps starting at the water appliance level. Most urban water models use a hydraulics-based conceptualization of the urban water network, simulating actual water flows, including runoff, potable water and wastewater. UWOT uses an alternative approach based on the generation, aggregation and transmission of a demand signal, starting from the household water appliances and moving towards the source. The simulation results in the estimation of: i) potable water demand, ii) water level changes inside the tank and reservoirs, iii) leakages, iv) evaporation, v) runoff, vi) urban water cycle energy consumption (including both energy required for water circulation, e.g. pump of rain-water inside tank, and energy consumed by the water appliances, e.g. heat water for showering), vii) capital and operational costs. More details on UWOT can be found in the publications of Makropoulos *et al.* (2008), Rozos and Makropoulos (2012, 2013), and Rozos et al. (2013).

c. The detailed design and detailed research level (consultants and engineers).

This encompasses development work and implementation on interactions of various ecosystems services provided by BG Solutions and their optimization. It involves detailed modelling of complex interactions between individual ecosystems.

The future of this approach is based on a common platform that ties in the individual models into an Integrated Modelling System (IMS). It also involves modules developed by the Taiwanese (NTU) PhD students affiliated with the BGD project, which are integrating BG Solutions into BIM (Building Information Management), plus the microclimate module being developed by Ivo with Maarten, which will also interface with BIM.

A schematic of this solution is presented in Fig 8.

Whichever of the planning tools is used, it is important that consultation with the BG experts and spatial planners/architects on the formulation of the integrated solutions based on optimised interactions of ecosystem services starts as early as possible: ideally, at the very beginning of the planning process. This is shown in the lower part of Fig 9, as opposed to late stage engagement, which is presented in the upper part in the same figure.

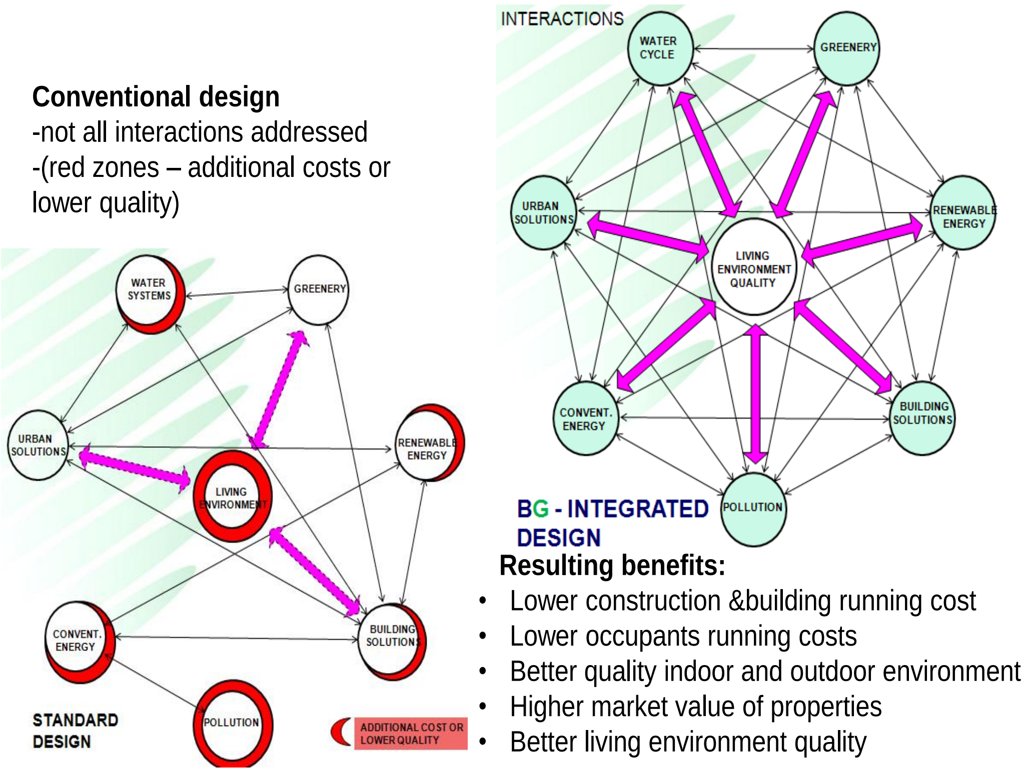

Figure 8: The concept of the optimal ecosystem performance based design method

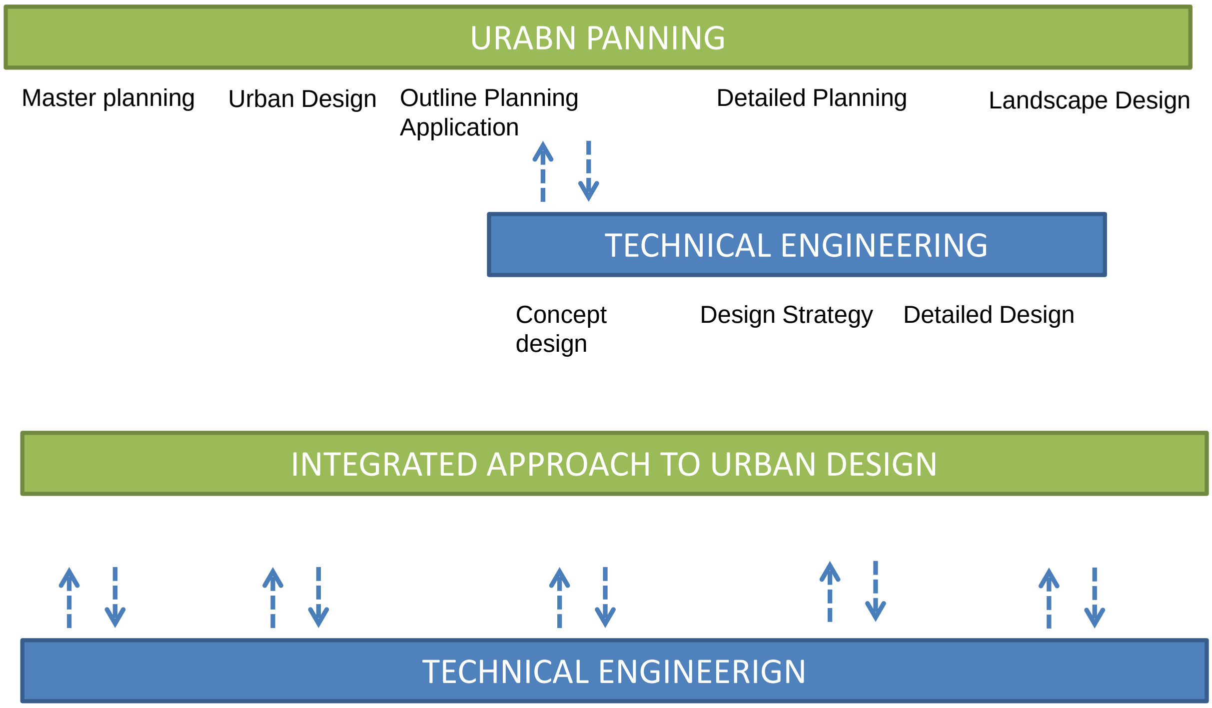

Figure 9: Schematic of when to start consultations on "sustainability": (a) current practice, after the master planning and urban design (upper scheme or (b) before the tender document is written or at the tender phase

3 Part 2: Methodology, Examples

3.1 Introduction to implementations of BG Solutions

Although the concept of BG solutions is relatively new (the BGG project started in the late 2012) it is gaining momentum at an international scale. The United Nations University has commissioned a study (Rethinking Infrastructure Design for multi-use Water Services) on implementation of BG Solutions in new projects and their retrofitting into existing developments. This study is being conducted by the BGD team.

BG Solutions are based on good practices performed before the project's commencement. Added value is maximised for projects where the BGD concept is embedded in the whole planning and implement process. In what follows, some of these examples are presented.

When the problems of climate change became evident (through weather extremes) many people thought about our relationship with the environment. Even in the 1970`s, questions of population, food production, industrial production, pollution and consumption of non-renewable natural resources arose, as did the long-term viability of modern cities.

The traditional approach to engineering design of structures and systems exposed to impacts of stochastic conditions (variables) has been to adapt the acceptable risk (thus costs) to the selected return period. However, climate change creates a lot of issues to this methodology since the systems designed to sustain a certain return period are now exposed to extreme conditions more frequently. Recently, Fratini at all (2012) "customised" this method by introducing the so called Three Points Approach (3PA) for analysis of adaptations to climate changes. If one single function (flood mitigation, for example) of a technical system is analysed in isolation, in order to adapt for climate change one would have to invest heavily into increasing its capacity ("rich men's solution"). BGD project has further customised this methodology to support climate change adaptation through trans-disciplinarity and multi-functionality by linking this approach to the integrated optimisation of BGD based, eco-systems' performance ("wise men's solutions").

The BGD project has formulated its paradigm here as "we need to evolve from a monoculture - rich man's solution - to more sustainable multicultural (multifunctional) ones– a wise man's culture. That means that the simplistic, `solve one pressing problem at a time` approach of the nineteenth century will need to be changed into long timescale thinking in terms of ecosystems and networks, bio-geochemical cycles and chains of cause and effects. One of the most challenging issues in modern cities is water. Water issues often remain disconnected from the broader urban planning processes.

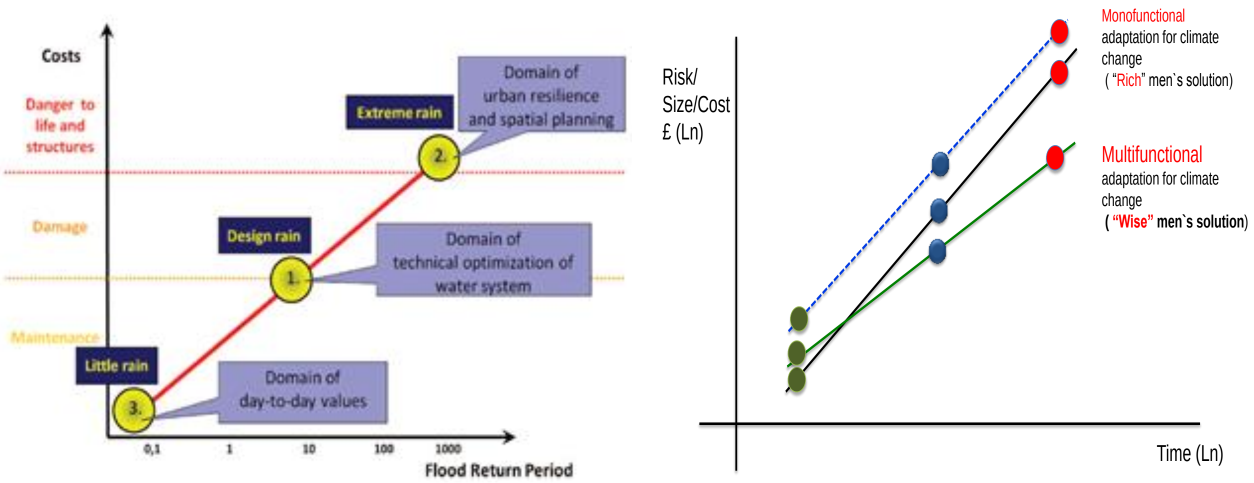

Figure 10: Options for adaptations to climate change: a. Conventional design approach classified by (Fratini et. al (2012)) through 3PA and b. adaptations for climate change through transdisciplinarity and multifunctionality

3.2 Examples and case studies

3.2.1 University Campus Borongaj, Zagreb, Croatia

The first example is based on the solutions proposed for the new university campus Borongaj in Zagreb conducted jointly by the teams of Njiric arhitekti and EnPlus (partner in BGD project). The project, which covered an area of 450.000 m^2, was based on the following concept:

- The technical and financial effects of the BG approach are modelled and simulated with the world leading advanced BG modelling system.
- Impacts of BG Solutions are quantified and presented in an easy to understand form.

Some of the results obtained are (also presented in Fig 10):

1. **Without** the influence of greenery, modelled indoor temperature in the building would be 29.76ºC (figure on the left);
2. Simulated indoor temperature in the building **with** the influence of designed greenery (forest) around the buildings is 25.94ºC (figure on the right). Energy saving of 50 – 60% during extreme summer temperatures.
3.

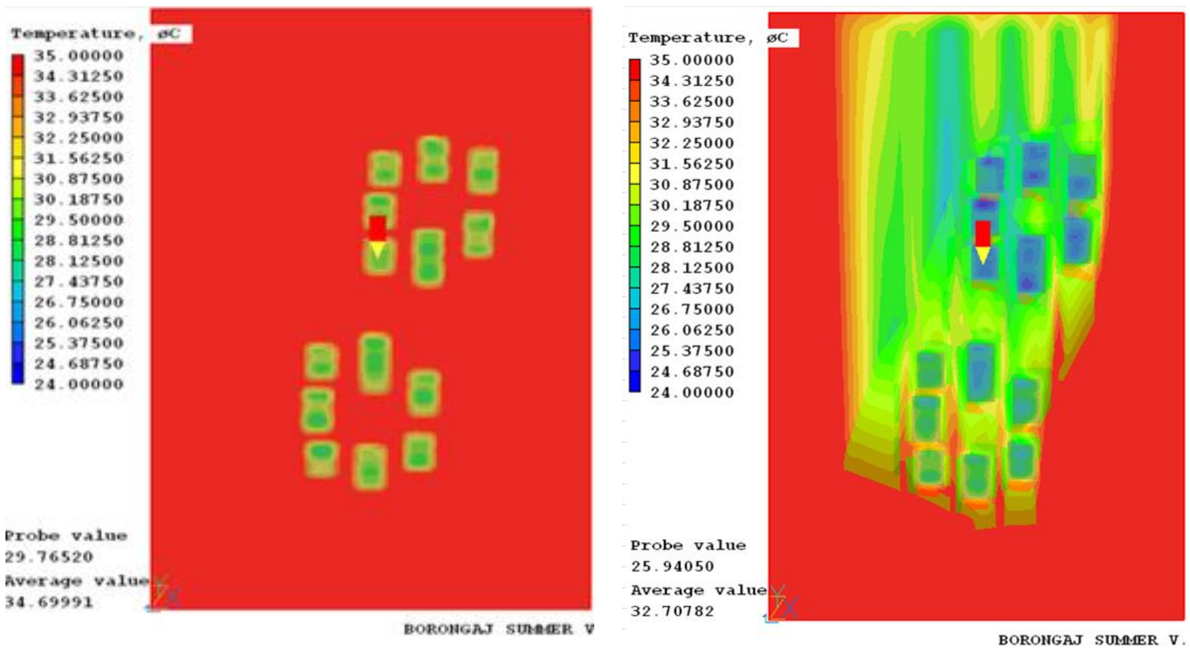

Figure 11: Improvement of the thermal regime based on the positive contributions of the combined impact of carefully designed vegetation (Fig 12) and its interaction with the building thorough the year.

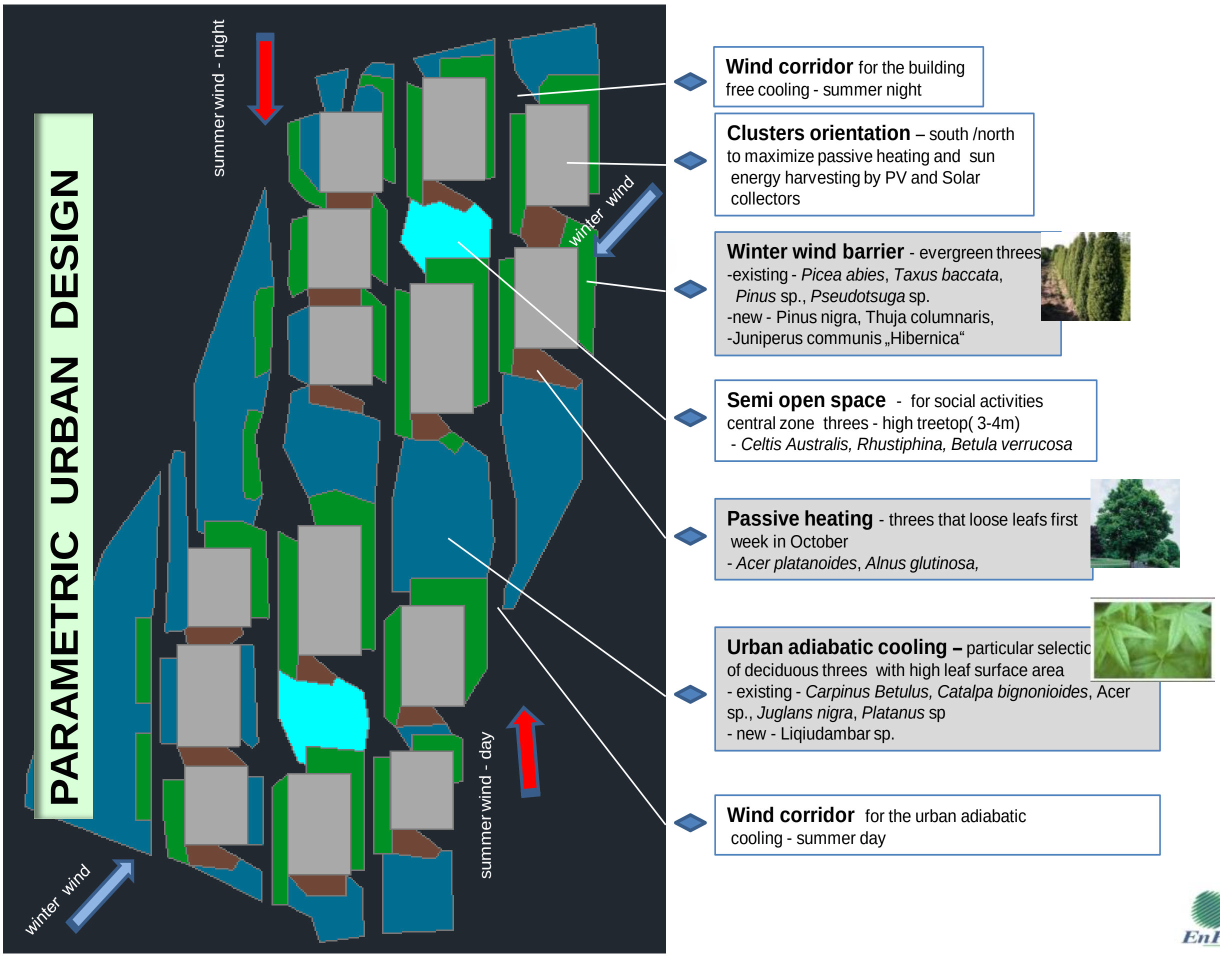

Figure 12: Schematic of urban vegetation designed for optimised solutions in Parametric Urban Design.

3.2.2 Retrofitting of the WB buildings

Figure 13 represents the initial and improved indoor environment quality of one of the World Bank buildings modelled by EnPlus (BGD project partner).

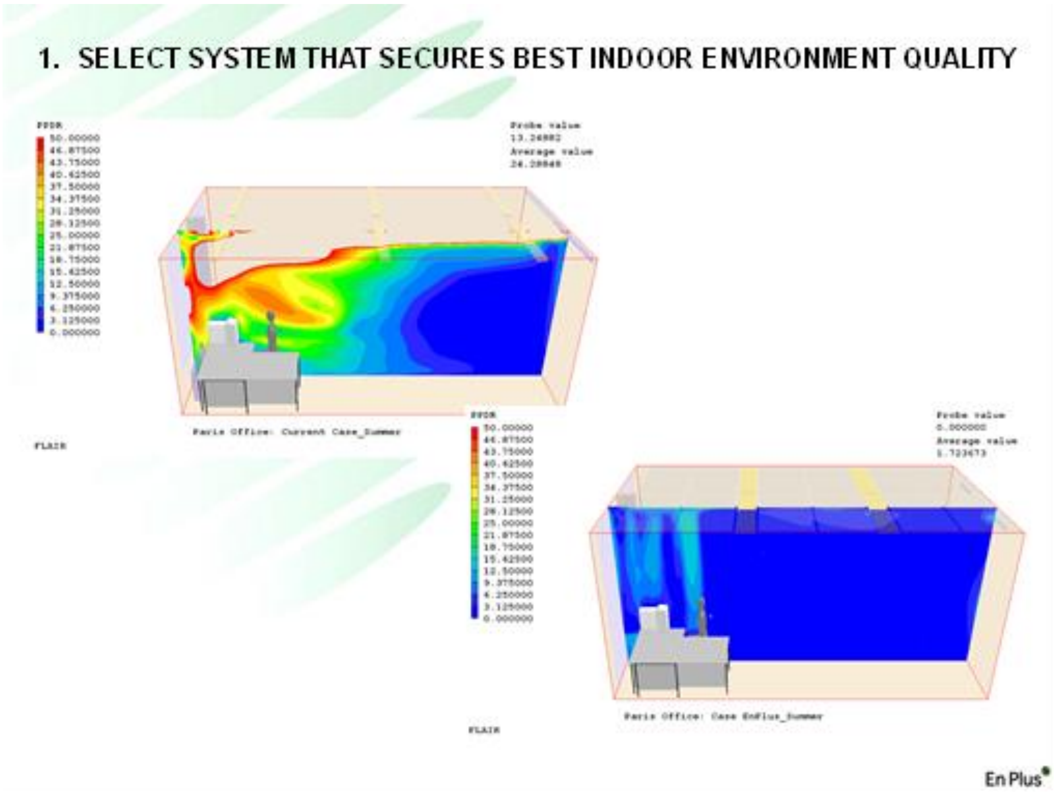

Figure 13: Integrated indoor environment quality of one of the WB buildings retrofitted by EnPlus

3.2.3 Gardens by the Bay project, Singapore

In the Gardens by the Bay project, some aspects of which are presented in Figure 14, a high level of complementary BG solutions is implemented. This includes a complex system of waste recycling for energy production. The site is planned to be used as BGD open air laboratory.

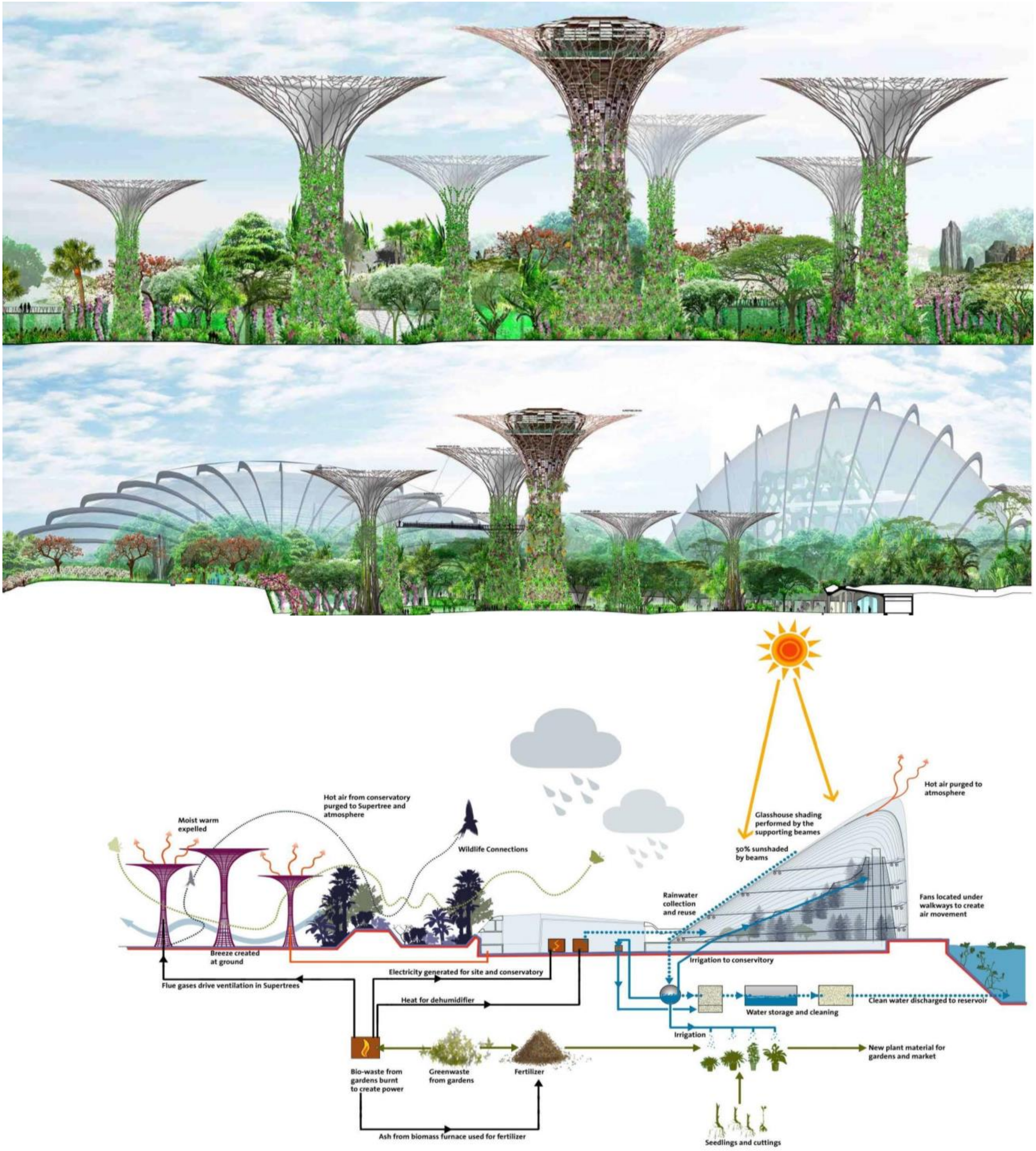

Figure 14: Gardens by the Bay, Singapore. To be used as a BGD open air laboratory

4 Conclusions

In addition to introducing innovative technology for the better planning of urban areas for adaptation to climate change, the Blue Green Dream (BGD) project presented in this paper serves as a platform for discussion of possible collaboration with and synergy of the BGD regional centers and the national focal points.

We have to realise and highlight differences between the new development, and the redevelopment / revitalization of already build-up areas. In both cases, the planning and management process of blue-green infrastructure require different solutions and different approach. However, both need to have a clear vision and measures in spatial planning procedures to allow the plans to be put into practice. Ambitions and plans are too often removed from the people living in the area of focus. Consequently, the solutions have not taken into account the peoples' needs. The overall objective should be to provide a better place for living. Urban planners are well aware of the benefits dwellers in urban areas have from vegetation. For vegetation to continue providing those benefits, it has to have a continuous water supply. Now is time to rethink all those benefits and to incorporate them into urban planning. The main goals of the techniques are improvement and management of urban ecosystem services including water quality, quantity and quality of life.

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The first author, Professor Čedo Maksimović, PhD (c.maksimovic@imperial.ac.uk), who coordinates this project is Head of the Urban Water Research Group-UWRG (www3.imperial.ac.uk/people/c.maksimovic) at the Department of Civil Engineering, Imperial College London. Professor Maksimović would like to acknowledge the financial support of the Climate_KIC program.

6 Bibliography and sources

Maksimovic, Č., Stanković. S., Liu, X., Lalić, M. (2013) Blue Green Dream project's solutions for Urban Areas in the future, Proc. of the Reporting for Sustainability Conference, Bečići, Regional Environmental Centre (REC).

Fratini, C.F., G.D. Geldof , J. Kluck & P.S. Mikkelsen (2012) Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through trans-disciplinarily and multi-functionality, Urban Water Journal, 9:5, 317-331.

Makropoulos, C.K., Natsis, K., Liu, S., Mittas, K., and Butler, D. (2008) Decision support for sustainable option selection in integrated urban water management. Environmental Modelling and Software 23 (12), pp. 1448-1460.

Rozos, E., and Makropoulos, C., 2012. Assessing the combined benefits of water recycling technologies by modelling the total urban water cycle, Urban Water Journal, 9(1), doi:10.1080/1573062X.2011.630096.

Rozos, E., and Makropoulos, C. (2013) Source to tap urban water cycle modelling, Environmental Modelling and Software, 41, pp. 139–150, doi:10.1016/j.envsoft.2012.11.015, Elsevier.

Rozos, E., Makropoulos, C., and Maksimović, Č. (2013) Water Science & Technology: Water Supply In Press, Rethinking urban areas: an example of an integrated blue-green approach, Vol. 13 Issue 6, p1534-1542, doi:10.2166/ws.2013.140.

UNU-Flores, Dresden (2014) Rethinking Infrastructure Design for multi-use Water Services (in press).

Household centred approach to water management

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Abstract

Increasing water scarcity in some regions is a strong motivator for water demand management. Generally limited resources, financial and natural, our high ecological footprint and changing systems, from society to global climate, should encourage us to optimise water use even in regions where we don't yet feel an immediate pressure on the resource. The search for approaches and tools optimising water use lead to the examination of developments in other disciplines and sectors. It also suggested a systemic approach to urban water and the re-examination of urban water systems was needed. One result of this exercise was to place the household at the centre of all efforts, because it plays a key role as both consumer and producer of valuable resources, which have to be managed appropriately at the household level to allow their further use, independently of the overall system the household is part of.

Key words: Household-centred approach, Sustainable water systems, Systemic approach, Water pinch, Water management

1 Introduction

Presently whatever water is needed in settlements is normally brought from outside, sometimes quite a long distance. It is treated to potable quality, distributed throughout the settlement in mains and used for almost all imaginable uses, from drinking to sewer cleaning. After one use the water is considered a waste, collected and carried away to a wastewater treatment plant, where a great effort is made to bring it back to a quality which allows its release into the aquatic environment, counting on the capacity of this environment to receive and neutralise a certain amount of harmful substances. Rainwater, which directly falls on the settlement, is called stormwater and considered at least a nuisance if not a hazard from the outset, collected and carried away to the nearest possible point of the natural drainage system to be released there with an intermediary treatment in some cases. Entire rivers crossing settlements have been canalised or directed into underground pipelines and carried away.

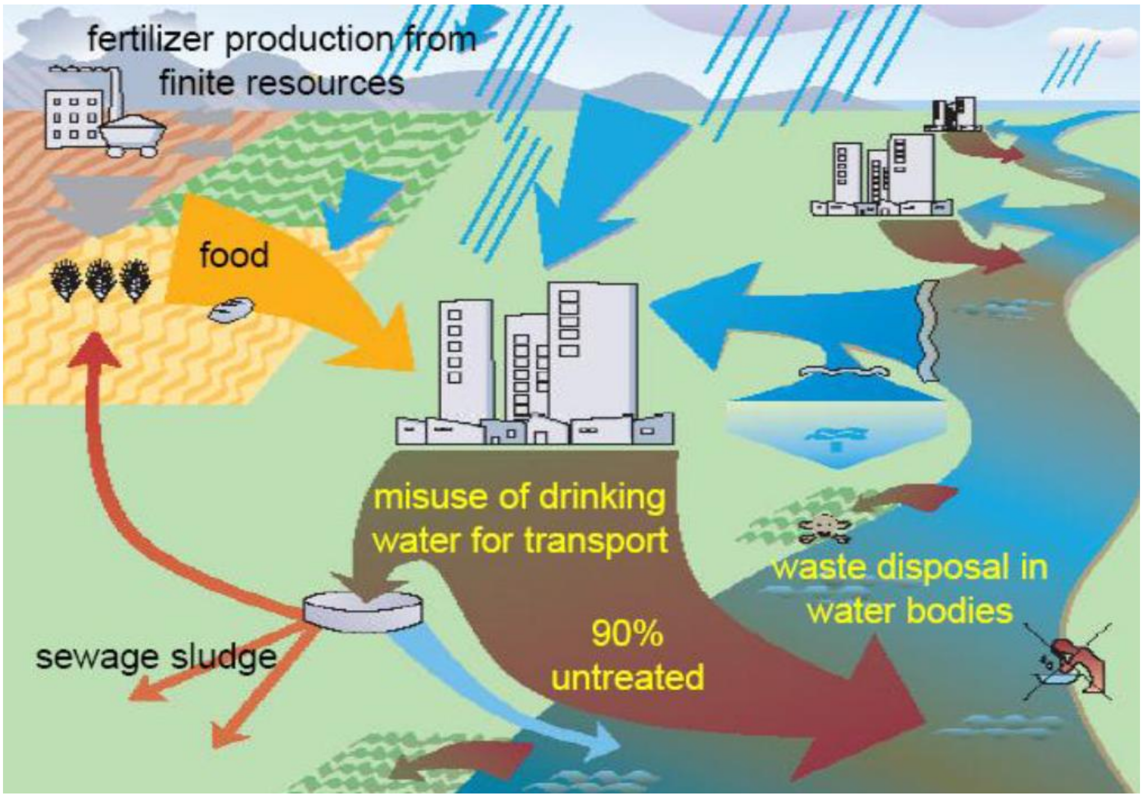

Figure 1: Present water use

This water management system, while providing for the needs of settlements in terms of water and protection, causes high cost, which only part of the global population can afford, and has other substantial limitations, comprising the following list:

- Water utilities have to produce much more potable water than is really needed
- Water infrastructure is inflexible due to its high cost
- It thus has problems to adjust to changing conditions, e.g. climate, population, user behaviour, security issues or technology
- Which means that independently of cost, inefficient technologies are perpetuated, under the impression that changes would be too expensive but often to serve private interests
- The direct evacuation of stormwater has a negative impact on floods and ground water recharge
- Sealing of surfaces and evapo-transpiration reduction lead to higher local temperatures, i.e. urban heat islands
- Which in turn lead to more energy demand for cooling and more particulate matter form surrounding agricultural land through convection currents
- Quality of life is ultimately reduced through this kind of water management

Given this list of shortcomings it can be expected that the way we manage water contributes to the high footprint we presently have. The list of problems can be turned around and transformed into a list of assets. Thus real estate prices immediately respond positively to an open water surface in the close vicinity, which can be a stormwater storage basin or a wetland for greywater treatment, attractively designed.

Inverting the list would lead to a higher diversity of systems to achieve more flexibility and adjustability. Various water sources would be used for different purposes and water would be retained in cities, to become apparent, a visible part of urban life, both human and non-human. This would ultimately have to introduce a new water paradigm.

Now high diversity in the kind of systems, and in their size, is a characteristic of nature itself. The natural water cycle is a very good example reaching from global exchanges to water transport within the cellule using a variety of mechanisms and all imaginable intermediary scales. Which other systems can lead to a better understanding of the challenge ahead and potential solutions?

The challenge is clearly an ecological footprint equal to or below what can be supported by the biosphere and the globe in general over a long period, i.e. sustainability. It can also be postulated that in a finite environment substances, which are released into that environment are coming around. There is no such thing as final disposal. For substances released there is only planned or unplanned reuse.

2 Methods

The search for a new water paradigm can start with nature. Nature on earth, the entire biosphere, has had a development time of roughly 4.5 billion years. Most of the questions we ask, have already found several answers during this time and the answers are tested and proven (Benyus).

Humans certainly also had their share in developing appropriate answers. In the search for a new approach to water, which other human experiences could be helpful, was one question to ask. And what approach to adopt to develop and test a new paradigm?

The study of changes in other sectors was one basis for the work. The energy sector undergoes a revolution. From centralised, large systems and heavy infrastructure for the exchange of energy over long distances it is progressively transformed into a localised, smart but still interconnected set of highly varying entities. Solid waste is another such example. Collecting all waste together, as is done for wastewater, and then trying to turn it into a resource has proven to allow but the crudest forms of reuse. Any more sophisticated use of waste materials needs a different approach. The water sector itself, far from being homogeneous, offers good practice examples, e.g. with sustainable solutions for developing countries or those developed in industry through the cleaner production approach.

The energy sector looked at houses and developed passive and than plus energy houses. What would a water passive house look like or a plus water house, a house actually producing more clean water than its inhabitants used?

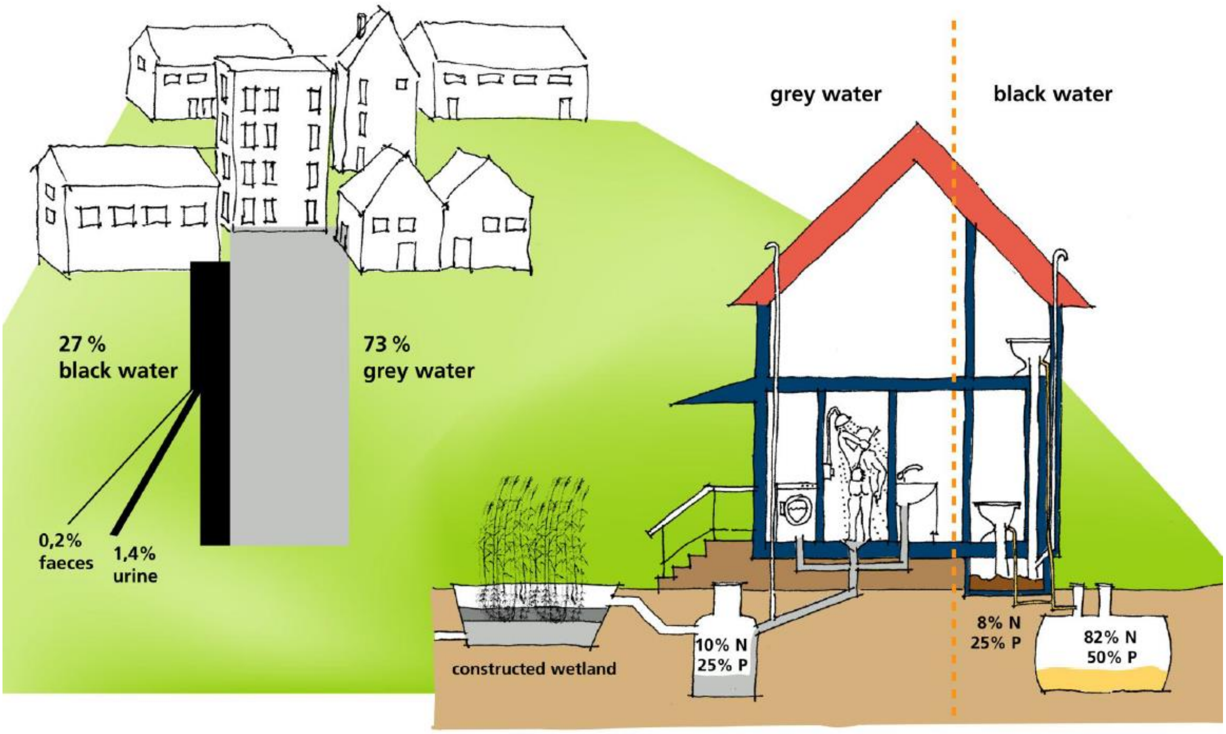

Figure 2: Percentage of sewage components of European households

Another approach was to learn through pilot implementations of own and other initiatives. The work was carried out in a "project spiral" repeatedly comprising the following steps (see figure 3)

- Development of a theoretical approach
- Screening of technology
- Development of tools for implementation and operation, i.e. design tools, decision making processes, regulations
- Evaluation and planning of the next cycle

The approach was checked and approved through the implementation of pilot cases resulting from the project work.

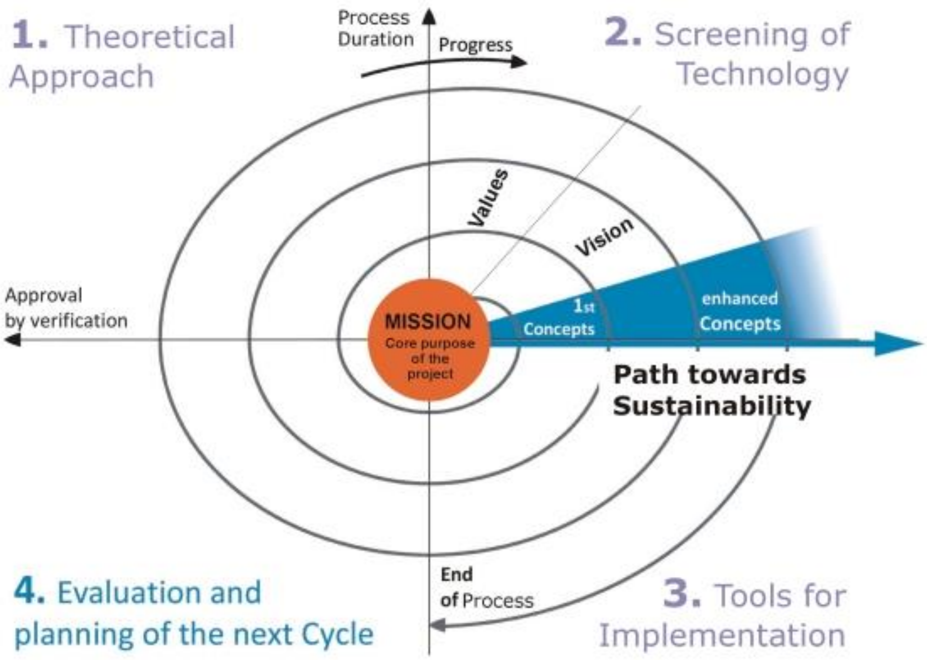

Figure 3: Path towards Sustainability

Projects and initiatives which directly or indirectly contributed to the development mission are listed in table 1.

Table 1: Projects and initiatives that contributed to the mission

Participation	Observation, some kind of partnership
▪ SWAMP, Zer0-M, Susana	▪ Netssaf, Durban, Erdos Eco-Town Project, Ecosan Ouagadogou
▪ NASPA	▪ Empowers
▪ Workshops of “Green Cities”, COST proposal, EdiCit	▪ Sustainable Sanitation Alliance
▪ Casablanca Urban Agriculture	▪ SWITCH, Restorative Buildings
▪ Gugler Leuchtturm and Cradle to cradle printing shop	

The approach started with the aim of an integrated water and wastewater management. This led to a zero outflow postulation, which revealed the need to also deal with the solids in water, especially plant nutrients and develop an integrated closed loop substance flow management. At that stage it became clear that such an approach could only be realised within an integrated and participatory multi-sectoral process of decision making, implementation and operation.

Implementations at the various stages comprised pilot plants, which helped to evaluate the approach, and led to the next cycle of reflection and implementation.

Stage "integrated water and wastewater management":
SWAMP pilot of phosphorus reduction in an effluent through elimination of the phosphorus source, a particular detergent of the connected restaurant kitchen, or water consumption reduction leading to a reduced size of the treatment wetland at Karawankenhof through the purchase of a water efficient new dishwasher, a measure which was immediately cost effective, too, given that the dishwasher was cheaper than the wetland volume corresponding to the difference in the hydraulic load of the water saving.

Stage "zero outflow"
Training and Demonstration Centres in the middle of densely built Mediterranean towns, for greywater treatment and irrigation, SEKEM wastewater treatment for reuse in timber production.

Stage "local reuse"
Gugler Urine Diversion Dehydrating Toilets for co-composting of excreta with waste paper from the printing to yield compost with high nutrient content for organic urban gardening of produce which will supply the canteen with high quality food. Paper and inks were selected to be "edible", i.e. not to contain any harmful substances for food production.

The examples above are all decentralised implementations, but that is more a result of the attempt to suggest new solutions, which can only be implemented as pilots, rather than a necessary condition for sustainable systems.

3 Results

More advanced sectors than water show that it is inevitable to pay attention at every step or stage of a material flow cycle. Thus solid waste is separated at the site of production, the household, the factory or actually the process within the factory, collected and processed in sequences where one step does not negatively impact the next. Actually the cradle to cradle approach postulates that even the product design before its first use, before the household, should take into consideration how, after the use, a particular product can best be kept in a substance cycle.

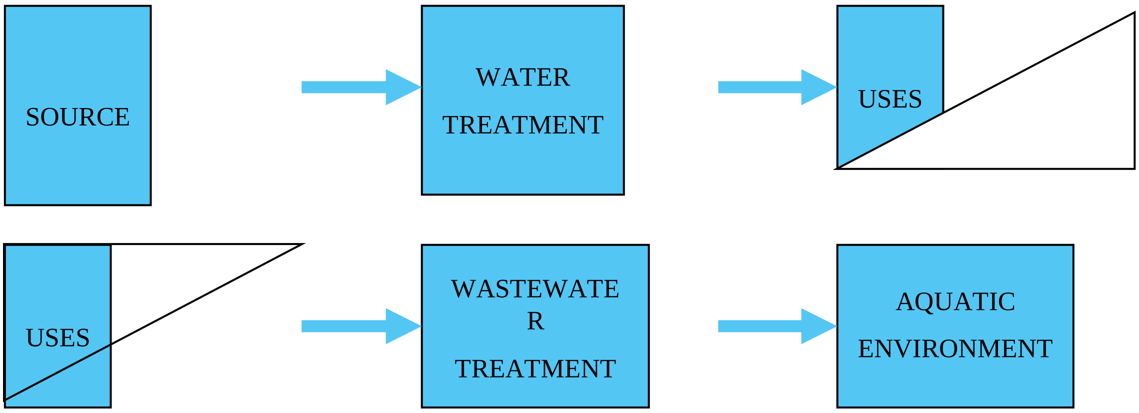

Figure 4: Usual water and wastewater scheme

Presently water for households is still a two stage linear process, the potable water supply and the wastewater disposal, with a clear division at the household level. Until recently the common understanding was that there can be no interference in household management of resources. Figure 4 shows the usual understanding of the two separate systems.

Reality however is quite different. First of all it is clear that the user is an important link in the path of urban water. This has been recognised by many cities with more or less successful attempts at reducing water demand through awareness raising or tariff programs. This is however but one aspect of the user's impact on the water flow.

Especially in dry countries the designation of wastewater rapidly appears inappropriate, as there is no water to waste actually. Thus wastewater is just another kind of fresh water with some additional substances. Some of these can be put to use, e.g. plant nutrients N, P and K in agriculture, others are harmful or unwanted in particular applications. Thus a treatment for the conditioning of the water or particular substances contained may be necessary. For most of the possible further uses treatment of freshwater used once in a household is easier, cheaper and more energy efficient, than desalination. Cyprus is one good example, where water saving through reclamation of processed water is strongly encouraged and financially supported by the government, as it is "four times cheaper than the same amount of water provided to the same tome from new projects" (Kambanellas 2007).

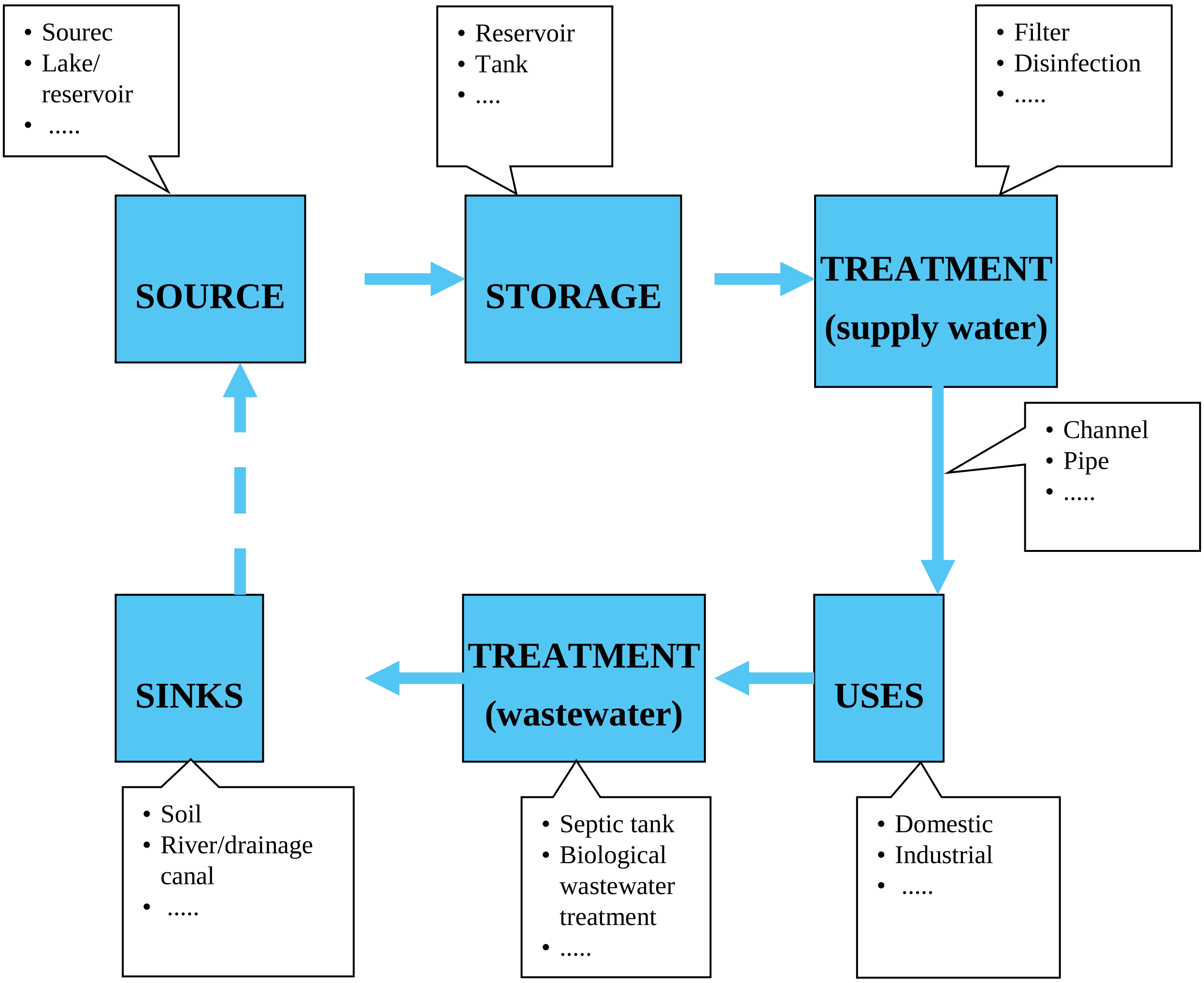

Figure 5: Complete water scheme

The user thus not only becomes "consumer" of potable water but also producer of service water, which he uses again for particular applications. Not only is the separation of water supply and disposal removed because the user is an active and important link between the two lines, but even the separation at the other end also disappears, because the sink for used water becomes source of new water. The real system thus is much closer to Figure 5, a loop, or at least a cascade, where one's sink is the next one's source. For optimisation of the water use, it is important always to work at the whole cycle or all the steps of a cascade.

When the Water Supply and Sanitation Collaborative Council (WSSCC) set together at Bellagio in 2000 to prepare recommendations for the UN General Secretary for the solution to the lack of sanitation in developing countries, they came up with the household centred approach. The idea was that any sanitation issue should be addressed at the smallest possible level. Only if no solution could be identified at the lowest level, the search should continue at the next higher level, from household to neighbourhood to town, province and country or even trans-boundary river basin (Figure 6).

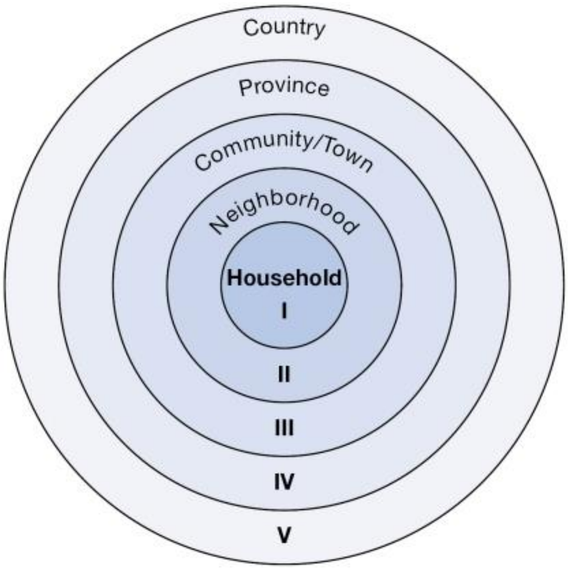

Figure 6: Household centred approach (EAWAG 2005) for domestic wastewater

As shown above the household level is not only a key element for sanitation in developing countries. This is true for the entire urban water cycle in any setup. The household on one hand is user of water, and can use more or less. It can use the water mains or a choice of other sources, e.g. roof or non-roof stormwater, treated greywater or wastewater, which significantly increases the efficiency of water use (

Table 2). On the other hand the household also becomes producer of a variety of flows, which can be mixed or collected separately and used as service water, fertiliser, etc.

The equivalent of the household in production of goods is the process. One of the first cleaner production initiatives was started in 1992 in Austria, predating the household centred approach. Cleaner production has developed tools to design cascades and optimised multi-source systems according to pre-selected criteria. Industry had learned from efficient energy use, resulting in the heat pinch analysis, to do the same for water and developed the water pinch analysis (Wang and Smith, 1994). This was further developed to the water management hierarchy (Manan et al., 2006) and the cost-effective minimum water network resulting in the systematic hierarchical approach for resilient process screening (SHARPS) (Wan Alwi and Manan, 2007). Why shouldn't tools developed for water demand minimisation in industry be applicable to households? Actually SHARPS was developed for both, industrial and domestic applications, but while applied in industry has still to find its way into domestic urban water planning.

Table 2: Differential use of water resources, 1 preferred, 2 compatible, 3 non-preferred, 4 non compatible use (Ecological Engineering 2003)

USE	Garden	Kitchen		Laundry		Toilet	Bathroom	
		Cold	*Hot*	*Cold*	*Hot*		*Cold*	*Hot*
SOURCE								
Potable Water	3	**1**	2	**1**	2	3	**1**	2
Wastewater								
Treated Wastewater	**1**	4	4	4	4	**1**	4	4
Greywater	2	4	4	4	4	2	4	4
Stormwater								
Roof	2	2	**1**	**1**	**1**	2	2	**1**
Non-roof	2	4	4	4	4	2	4	4

Figure abovesuggests that there is a link between supply and disposal of water not only at the user stage but also between the sink and the source of water. There are obvious examples of such a closed cycle, e.g. when greywater is treated and used for laundry, which then is again collected as grey water. Our existence in a finite environment however suggests that we are actually limited to planned or un-planned reuse of actually any resource, including water. Authors speak of broken or closed cycles. An overall optimisation is only possible, if the whole cycle from source to source, in a cradle to cradle approach, is examined and dealt with.

All stakeholders, at every stage of the cycle, have to be involved and participate in order to make a new solution possible, water supplier, user, wastewater utility, authority. Thus decision making and design must be participatory and process oriented, as the processes have to be adapted to each particular case, compared to using just one set of standard processes, which everybody knows already before and reflection starts.

Operacija se izvaja v okviru Operativnega programa razvoja človeških virov za obdobje 2007-2013, razvojne prioritete 3 : »Razvoj človeških virov in vseživljenjskega učenja«; prednostne usmeritve 3.3 »Kakovost, konkurenčnost in odzivnost visokega šolstva«.

Every step of the cycle must be examined according to the three aspects laid out by the report "Zukunftsfähiges Deutschland in einer globalisierten Welt" (BUND, 2008).

- **Sufficiency** – Is water needed, which kind of water or water quality is needed?
- **Consistency** with the environment: not just less harmful – how can we be beneficial, what can we contribute, what ecosystem service can we provide
- **Efficiency** - how to use as little as possible in order to treat as little as possible, have the smallest possible infrastructure, energy use,

The steps have to be examined in this order. It makes no sense to improve the efficiency of an approach harmful to the environment. It may become even more harmful or less harmful at best, but not beneficial, which it should be.

Several cycles have to be examined, for water, possibly for partial flows, of different sizes, eg. recycling treated greywater on site and collecting and further using black water in neighbourhoods, harvesting and using stormwater which is part of the global water cycle, but also cycles for substance in the water, e.g. plant nutrients or carbon, as well as the energy flows.

4 Discussion

It is clear that in our finite environment ever substance follows cyclical paths. It however only slowly reaches our social conscience that we as humans have reached a number and size of impact that this is relevant for us. We have long considered the globe to be boundless compared to our activities. This is no longer the case. Thus, instead of relying on unplanned reuse and hoping this will turn out fine, we'll have to plan our substance cycles carefully. This is, among others, particularly true for the water cycles we are involved with, from the global water cycle to those we can and probably must establish in our households. That however is a new paradigm in water management. One key question with new paradigms is, how to make them happen.

The pilots and reflections revealed that implementations in larger numbers or sizes are only possible with the participation and support of all stakeholders. The process suggested that we need a paradigm change in water supply and sanitation, but that it has to be accompanied by a more general changes, e.g. the entire city, but also social changes. This is a conclusion of several similar efforts towards sustainability, e.g. the 2000 W society at Zurich.

The social change comprises a change in the perception of wastewater from a nuisance to a resource. It will have to be treated accordingly, even from a technical point of view, i.e. we'll take care of it in order to be able to obtain readily usable products. That is where the household, respectively the equivalent unit production entity is concerned. The household will become a production unit, too, for what we call wastewater now as input and clean water, energy, carbon or biosolids and plant nutrients and by extension biomass or even food as output. We will play a similar role in the biosphere than ants, enhancing "ecosystem services" or life indeed, if we want to achieve a similar life time as a species than ants have done so far.

5 Bibliography and sources

Benyus, J. (2014) Biomimicry in action. TED Talk Video, TED Global 2009, www.ted.com/talks/janine_benyus_biomimicry_in_action, 2009, 1-6-2014.

Bund für Umwelt und Naturschutz (BUND) (2008) Brot für die Welt & Evangelischer Entwicklugsdienst (edit.): *Zukunftsfähiges Deutschland in einer globalisierten Welt. Ein Anstoß zur gesellschaftlichen Debatte*. Study by the Wuppertal Instituts für Klima, Umwelt, Energie. Fischer-Taschenbuch-Verlag, Frankfurt.

EAWAG (Swiss Federal Institute of Aquatic Science and Technologies) (2005) Household-Centered Environmental Sanitation, Implementing the Bellagio Principles in Urban Environmental Sanitation, Provisional Guidelines for Decision-Makers, June 2005.

Ecological Engineering (2003), Landcom Water Sensitive Urban Design Strategy – Design Philosophy and Case Study Report, report prepared for Landcom, NSW.

Kambanellas, C. A. (2007) Recycling of Greywater in Cyprus. *Sustainable Water Management:* 1-2007, 27 - 30.

Manan, Z.A, Wan Alwi, S.R. and Ujang Z. (2006) Systematic Design of a Maximum Recovery Network for an Urban System Based on Pinch Analysis, IEM Journal. 1 (67): 57 – 64.

Wan Alwi, S.R. and Manan, Z.A. (2007) A new holistic framework for cost effective minimum water network in industrial and urban sector. Journal of Environmental Management. 46, 5968 – 76.

Wang, Y.P. and Smith, R. (1994). Wastewater Minimisation. Chem. Eng. Sci. 49, 981 – 1006.

The potential of aquaponics for food production in the cities of the future

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Abstract

Urban farming is becoming a buzzword nowadays. It started as a grassroots movement, and entered the political agenda since early 2000. To establish urban farming on a sustainable scale beyond the pilot projects that seem to flourish in nearly every city with some self-respect, several components are necessary: social, economic, ecological. Visionary and provocative schemes such as Vertical farms (Despommier, 2009, 2010) and utopian renders by architects like Callebaut (DD 14 New Worlds, 2005) are widely disseminated and evidence public interest, but do not provide practical tools to address the situation with the technologies that are available now.
While recent accentuations seem to focus on social aspects, the scientific base for these endeavours should be strengthened as well. If food is to be grown in the city, it should be of high quality, not loaded with pollutants of both urban and agricultural origins. Innovations are required that simplify successful operations in urban gardening and enable cost-effective urban farming, while making these products safe for human consumption: new planting techniques, new varieties of produce, biological pest control, irrigation techniques, and integration with existing building infrastructures. Aquaponics has the potential to contribute to all these aspects.

Key words: Urban farming, Building integrated agriculture, Aquaponics, Zero Emission Buildings

1 Introduction

Human society in the 21st century faces many challenges. Growing urbanization and a growing population lead to increasing resource consumption. Between 2011 and 2050, the world population is expected to increase from 7.0 billion to 9.3 billion. At the same time, the population living in urban areas is projected to gain 2.6 billion, and by 2050 70% will live in the cities. Thus, urban areas worldwide are expected to absorb all the population growth expected over the next four decades, and continue to draw in rural population (United Nations 2012). Climate change is predicted to cause more environmental stressors in the future, while food production needs to be intensified. The required transition will require an increased flexibility of the urban environment, more sustainable use and re-use of natural resources as well as the adaptation of new infrastructure systems (Schuetze & Thomas, 2011).

In order to assure human health and wellbeing, the resilience of our food supply systems to cope with future hazards has to be strengthened. To build a nexus between water, energy and food we will need cooperation between different sectors, e.g. sanitation, drinking water supply, urban design, architecture, agriculture, and provisioning of energy.

Cities receive inputs, which accumulate and grow, are cycled, attenuated and transformed within the system, and produce outputs (Figure 1). The urban metabolism can be linear, cyclic or in between (Rogers 1997, Daigger, 2009). To enhance the resilience of cities, the flow-through economy should be changed to cycling systems, wherever possible.

2 Integration of food production into the cities

(Re-)integration of food production into the city is a necessary element to achieve the circular metabolism. While urban agriculture cannot supply all of cities' needs, there is inherent environmental logic and resilience within recognised historic models incorporating urban food growing such as those by Johann von Thünen (1826, cited in van der Schans & Wiskerke 2012) and Howard (1902).

Food grown in the vicinity of the consumers will also reduce the dependency on transport of goods ("Food Miles", Paxton 1994), energy and consumables. It will contribute to improved health (Rex & Blair, 2003). Plants provide ecosystem services for the city (enabling nutrient recycling, mitigating urban heat island effect, reduce storm water runoff and food transport needs) and enhance its living quality. Sustainable city farming can produce excellent quality food, thus contributing to public health. The water and nutrient demand can partly be met by source-separation of domestic greywater, treated on-site and reused for irrigation, and by rainwater harvesting.

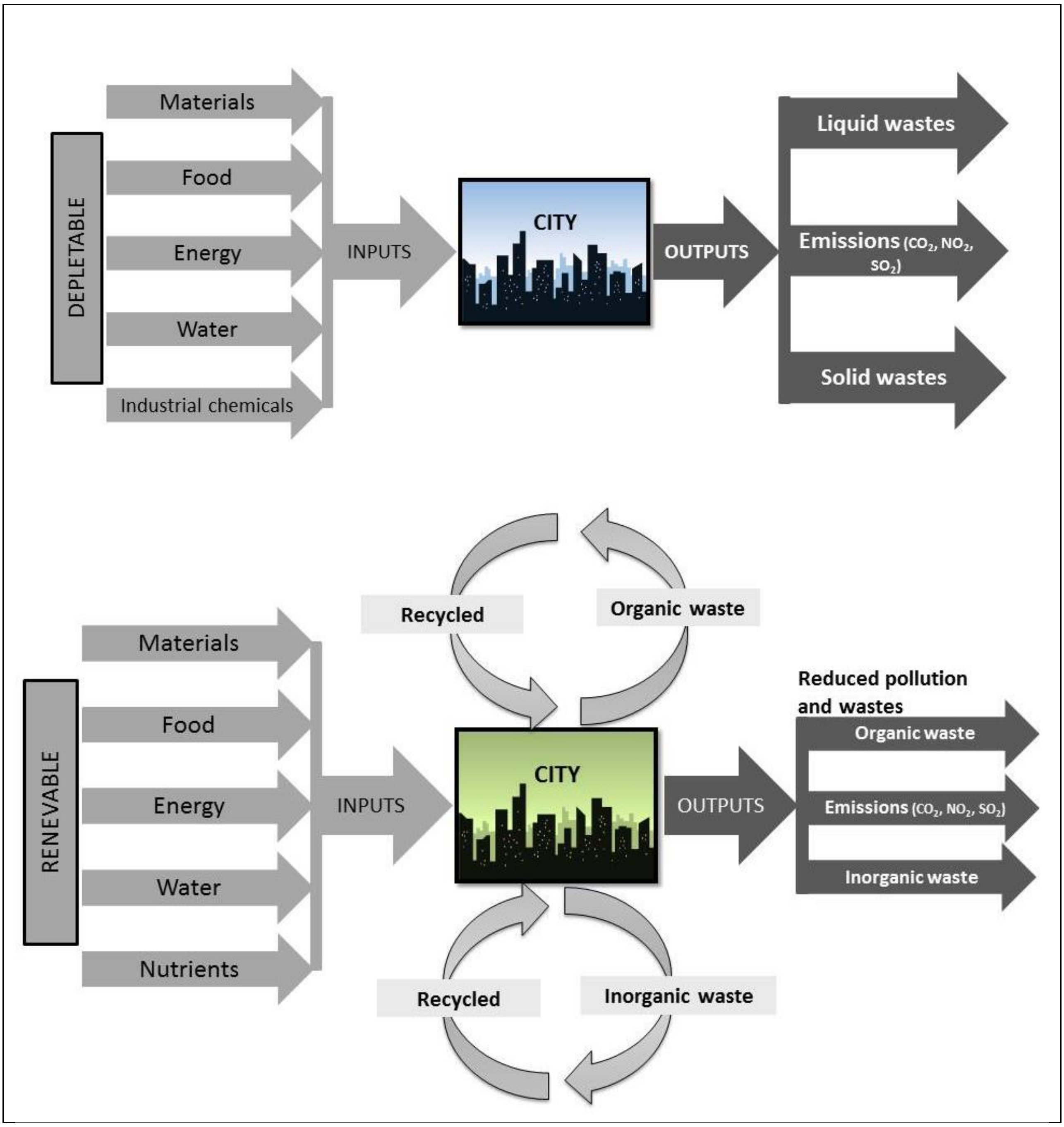

Figure 1: Linear (above) and circular (below) urban metabolism systems
Source: Adapted from Rogers 1997 and Novotny 2010

Urban Agriculture has the potential to simultaneously address multiple needs at a variety of scales (Figure 2, Table 1). Food production can be practiced at small, private scale, or at a commercial scale, linked to jobs and business opportunities for SMEs within the city or its immediate vicinity.

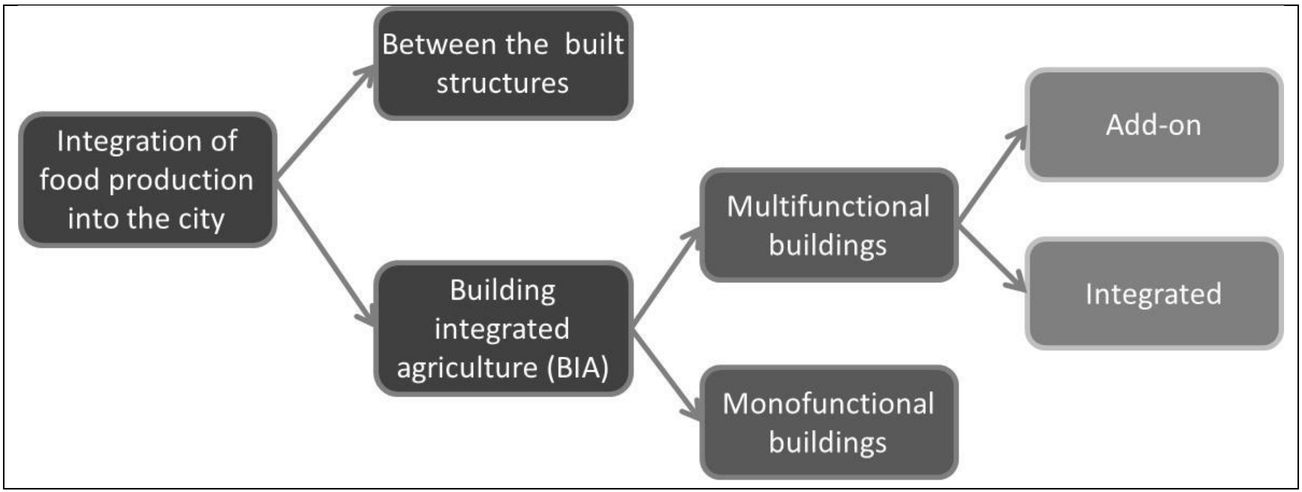

Figure 2: Integration of food production into the city

Table 1: A rough categorisation of the possibilities of integrating food production in cities

Where	How	Examples	Sources
Between building infrastructures	Within or near the city	gardening (private scale): allotment gardens, community gardens, CPULS	Viljoen 2005
		farming (commercial scale)	
Building integrated agriculture (BIA)	Multifunctional buildings Add-on	green roofs, balcony gardens, aquaponic gardens aquaponic rooftop farms	Graber & Junge, 2009 www.urbanfarmers.com
	Multifunctional buildings	Integration of the food production into water, energy and biomass cycles within the building (Zero Emission Buildings)	Bühler, 2013, Bühler et al., 2014, Schütze et al. 2013 www.zebistis.ch
	Monofunctional buildings	Vertical Farms: Buildings dedicated to food production	Despommier, 2010

Caplow (2010) defined Building integrated agriculture (BIA) as “the practice of locating high performance hydroponic greenhouse farming systems on and in mixed use buildings to exploit synergies between the built environment and agriculture”. Typical elements of BIA include recirculating hydroponics with/without aquaculture, waste heat captured from a building's heating-ventilation-air condition system, renewable energy supply, rainwater harvesting and treatment for a subsequent use in hydroponics and use of evaporative cooling. BIA can be of different designs, either open-air or encased in a greenhouse. It can be on the rooftop (horizontal) or integrated in the skin of the building (vertical). Soilless cultures are the core element of BIA (Figure 4).

3 Aquaponics

Aquaponics an innovative, sustainable food production system integrating aquaculture with hydroponic vegetal crops (Graber & Junge-Berberovic, 2009), (Figure 3). Aquaponics has the potential to play a key role in food provision and tackling global challenges such as water scarcity, food security, urbanization, and reductions in energy use and food miles. While it is a widely discussed technology today (about 1.3m hits on Google in May 2014), there are not so many research papers on the efficiency and performance published yet. The most cited ones include Diver (2000), Rakocy et al. (2006), Graber & Junge-Berberovic (2009) and Pantanella et al. (2010).

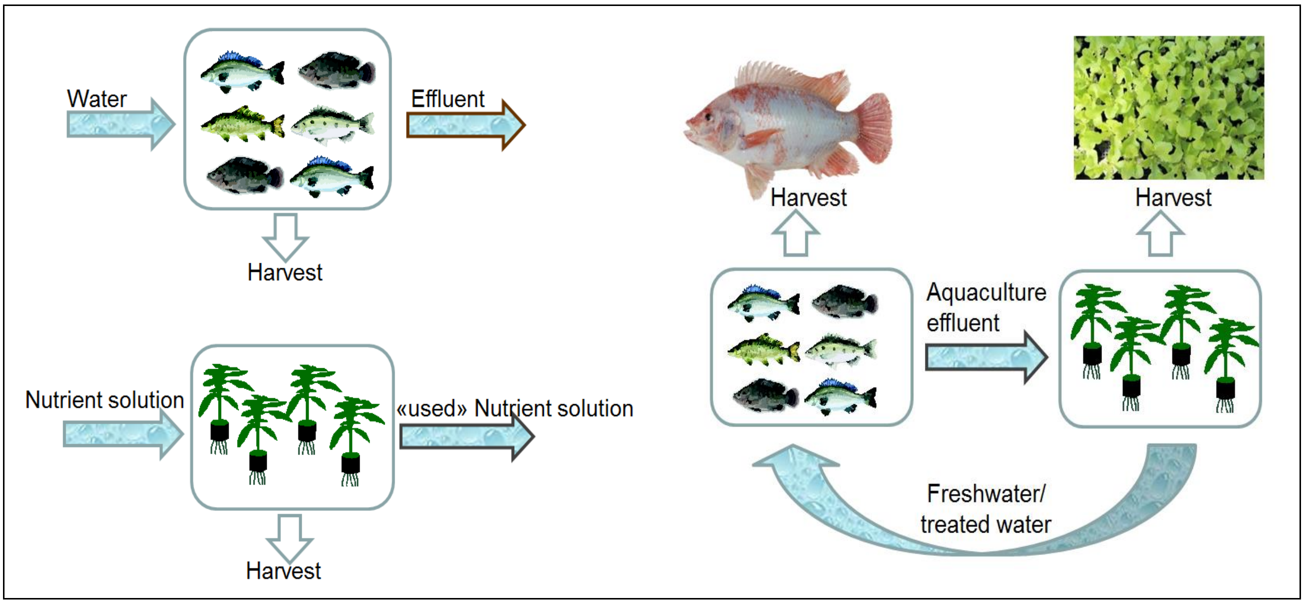

Figure 3: Aquaculture and hydroponics (left) and aquaponics (right)

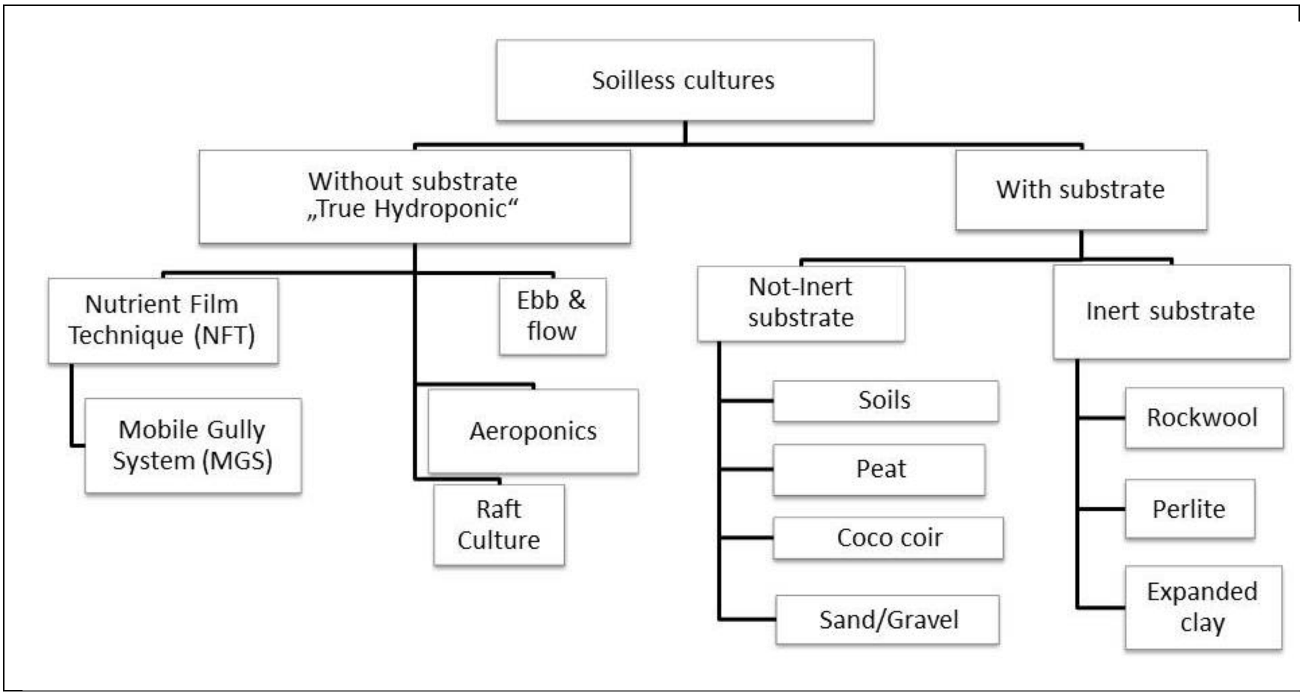

Figure 4. The taxonomy of soilless cultures.
Source: D. Bachmann, unpublished.

3.1 Opportunity mapping for Aquaponics

Aquaponic technology is not the panacea that will transform the cities of today into cities of the future. But, as the opportunity mapping the city of Basel (Table 2) shows, it can contribute up to 20% to the fish and vegetable consumption of a medium sized Swiss city.

3.2 The first commercial rooftop aquaponic farm in Switzerland

In 2012, the swiss company UrbanFarmers, a spin-off of the Zurich University of Applied Sciences (ZHAW) built a 260 m^2 greenhouse farm on an industrial rooftop in Basel (UF 2014). Together with the research team at ZHAW, the interior aquaponic farm layout was planned, installed, operated and monitored (Fig. 5). The project was approved and supported by the Swiss commission for technology and innovation during 18 months, focussing on the development of farm operation software in order to standardize this new farming approach. In its first year of operations, 700 kg Tilapia and 3’500 kg of different vegetables were produced and sold to restaurants as well as Migros, Switzerland’s largest retailer.

Table 2: Potential of urban food production within the city of Basel (UrbanFarmers, unpublished)

Aspect	**unit**	**Figure**
Total available vacant rooftop area in the city of Basel	m^2	2‘000‘000
Estimated potential for urban rooftop farms after filtering with key decision criteria: a) legal FAR (floor-to-area ratio) not yet reached b) situated in commercial & industrial zone c) roof has a carrying capacity of > 500 kg/m^2 d) roof size exceeds 500 m^2	% m^2	**5** 100’000
Production capacity	t/a	340 t fish 2‘000 t vegetables
Average consumption by Swiss consumers (BFS 2013)	kg/P/a	10 kg fish 80 kg vegetables
Number of persons served with the production	Persons	34‘000 for fish 14‘000 for vegetables
Population in the city of Basel	Persons	170‘000
Potential contribution to fish and vegetable consumption in Basel from urban rooftop farming	%	8-20

This UF001 pilot farm achieved three major goals: to showcase the proof of technology for aquaponic rooftop farms (it is possible to construct), to demonstrate proof of market acceptance by Swiss consumers for this new way of farming food (the UF brand was successfully introduced and embraced), and to deliver key performance figures that allow planning and scale-up for future commercially interesting farm units. UrbanFarmers is now offering this farming system to clients in a franchise model.

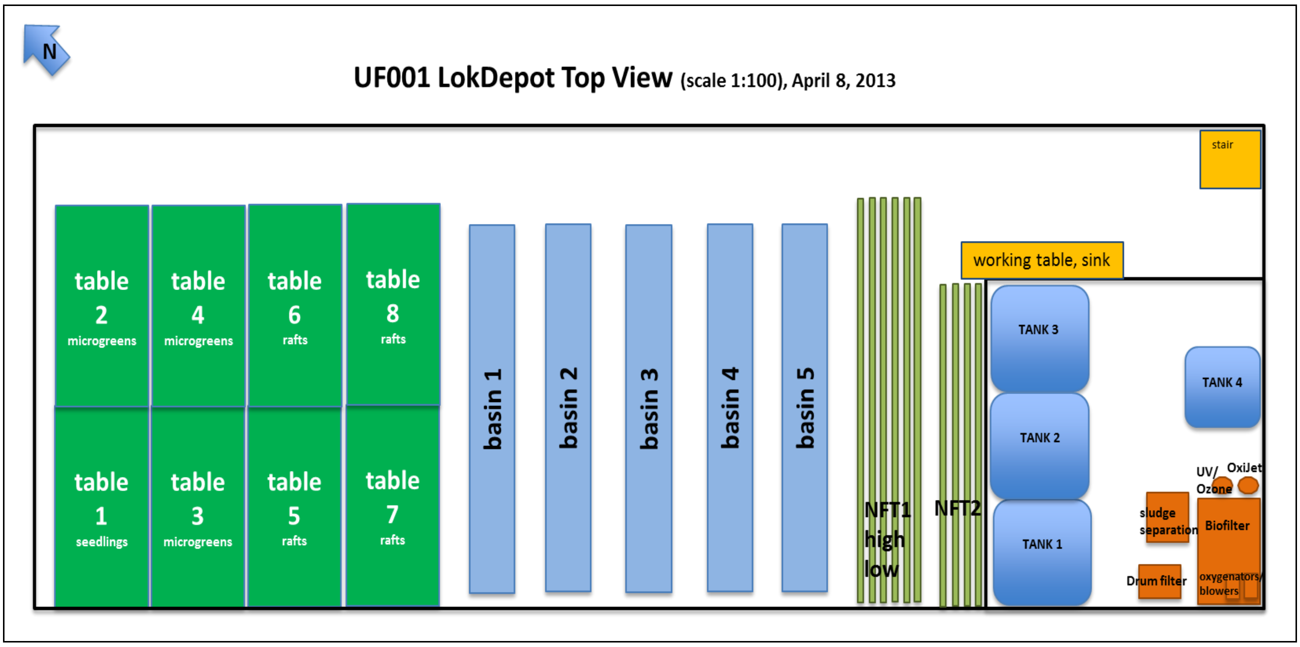

Figure 5: Floor plan of the world's first commercial rooftop aquaponic farm: UF001 LokDepot in Basel.
Source: UF (2014), http://urbanfarmers.com/projects/basel

3.3 Challenges and required research

If the technology is properly applied and monitored, it definitely has the potential to improve food security for cities, and exert the benefits outlined above. But Aquaponics also faces many challenges that require further research. These concern energy supply, reduction of energy demand through heat balance and greenhouse optimizations, improved lighting, climate control (humidity, temperature), rainwater harvesting and pretreatment, definition of optimal nutrient and pH levels for plants, optimal nutrition for fish, establishing a zero emission farm (reduction of solid wastes, composting of the fish sludge and plant waste), new varieties of vegetables and fish, and last, but not least pest and disease control. In line with the concept of Zero Emission Buildings (Schuetze et al 2013) the interfaces of rooftop farms with existing roof surfaces and building infrastructure ought to be integrated into the building.

4 Acknowledgements

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5 Bibliography and sources

BFS (2013). http://www.bfs.admin.ch/bfs/portal/de/index/themen/07/03/blank/data/01/04.html , www.bfs.admin.ch/bfs/portal/de/index/themen/07/03/blank/data/01/04.Document.21047.xls. Accessed in June 2014.

Bühler D. (2013). Best Practices of Zero Emission Buildings in Switzerland. Bachelor thesis, Institute of Natural Resource Science, Zurich University of Applied Sciences, Wädenswil.

Bühler, D., Schuetze, T., Junge, R. (2014) Towards development of a label for Zero Emission Buildings: A Tool to evaluate potential Zero Emission Buildings. *World Sustainability Forum 2014 – Conference Proceedings Paper* http://www.sciforum.net/conference/wsf-4. SUBMITTED.

Caplow, T. (2010). Building Integrated Agriculture: Philosophy and Practice. In: Heinrich-Böll-Stiftung (eds) (2010) Urban Futures 2030. Urban Development and Urban Lifestyles of the Future. Volume 5 (English Edition) in the publication series on ecology. Pp.54-58.

Daigger, G. (2009). Evolving urban water and residual management paradigms: Water reclamation and reuse, decentralization, resource recovery. *Water Environment Research*, 81(8):809-823.

DD 14 New Worlds (2005). Vincent Callebaut Architectures/ France-Belgium (Design Document). Damdi Architecture Publishing Co, Ltd.

Despommier, D. (2010). The Vertical Farm: Feeding the World in the 21st Century. ISBN 978-0-312-61139-2.

Diver, S. (2000). Aquaponics-Integration of hydroponics with aquaculture. Attra.

Graber, A. & Junge-Berberovic, R. (2009). Aquaponic Systems: Nutrient recycling from fish wastewater by vegetable production. *Desalination* 246:147–156. doi:10.1016/j.desal.2008.03.048

Howard, E. (1902). Garden Cities of Tomorrow. London, S. Sonnenschein & Co., Ltd. 1902. (at Google Books).

Novotny V. (2000). Footprint tools for Cities of the Future: moving towards sustainable urban water use. Water21, August 2010, p. 14-16.

Pantanella, E., Cardarelli, M., Colla, G., Rea, E., & Marcucci, A. (2010). Aquaponics vs. hydroponics: production and quality of lettuce crop. In XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on 927 (pp. 887-893).

Paxton, A (1994). The Food Miles Report: The dangers of long-distance food transport. SAFE Alliance, London, UK. http://www.sustainweb.org/publications/?id=191.

Rakocy, J. E., Masser, M. P., & Losordo, T. M. (2006). Recirculating aquaculture tank production systems: aquaponics—integrating fish and plant culture. SRAC publication, 454, 1-16.

Rex, D., Blair A. (2003). Unjust des(s)erts: food retailing and neighbourhood health in Sandwell. *International Journal of Retail & Distribution Management*, 31(9): 459-465.

Rogers, R. (1997). Cities for a small planet. Faber & Faber Limited, London. 180 pp.

Schuetze T., Thomas P. (2011). Sustainable sanitation systems as a key for circular economy – Three examples from Germany. 3. Internationales Symposium "Re-Water Braunschweig" 21. und 22. November 2011, Tagungsband, Braunschweig.

Schuetze, T. Lee, J-W, Lee, T-G (2013). Sustainable Urban (re-)Development with Building Integrated Energy, Water and Waste Systems. *Sustainability*, 5: 1114-1127; doi:10.3390/su5031114.

UF (2014). UF001 LokDepot, the world's first commercial aquaponic rooftop farm. http://urbanfarmers.com/projects/basel/

United Nations (2012). World Urbanization Prospects, the 2011 Revision: Highlights. New York. Accessed from http://esa.un.org/unup/Documentation/highlights.htm.

van der Schans, J.W. & Wiskerke, J.S.C. (2012). Urban agriculture in developed economies. In: Viljoen A., & Wiskerke, J.C.S. (eds) Sustainable food planning: evolving theory and practice. Wageningen Academic Publishers, The Netherlands. 598 pp.

Viljoen, A. (Ed.) (2005). CPULs - Continuous Productive Urban Landscapes - Designing Urban Agriculture For Sustainable Cities. Architectural Press, Oxford, United Kingdom. 280 pp.

REPUBLIKA SLOVENIJA
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Naložba v vašo prihodnost
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Evropski socialni sklad

Vegetated floating systems for multifunctional basins and water bodies in urban environment

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Abstract

The use of floating systems to sustain no-floating vegetation in water bodies can offer multiple ecological and functional services in urban environments, such as amelioration of water quality, aesthetics, shading, and sites to support biodiversity. The lecture will present the features of the floating systems, their flexibility in multipurpose objectives, the used plantings, and some case studies and applications.

Key words: treatment wetlands; multi purpose wetlands; ornamental plants; Tech-IA floating mat

1 Introduction

Floating Islands are an ecotechnology for remediating polluted waters and it has been used since the early seventies. This technique, known also as “floating treatment wetlands” (FTWs), allows to perform the water treatment directly within the water body (stream, river, channel, pond or lake). It uses different types of structures, like buoyant mats, to grab aquatic plants that are otherwise not floating, and floats them on the water surface. The plant roots grow through the mat forming a dense mass that extends into the water column below, either in calm or in running waters. Using this system it is possible avoid the use of huge surfaces usually needed for constructed wetlands, such as vertical or horizontal treatment wetlands. The (waste)water does not need to be drawn from its basin. Because they float on the water surface they can tolerate fluctuating water levels and are not constrained to shallow waters.

These systems improve water quality as well the aesthetic value of a water body with the presence of flowering species, creating new water environments for fauna and thus also obtaining better urban water spaces. The floating elements can be vegetated with herbaceous species with colourful blooms and these can be distributed along the seasons. Thus the floating islands can be used for ornamental purposes in urban setting.

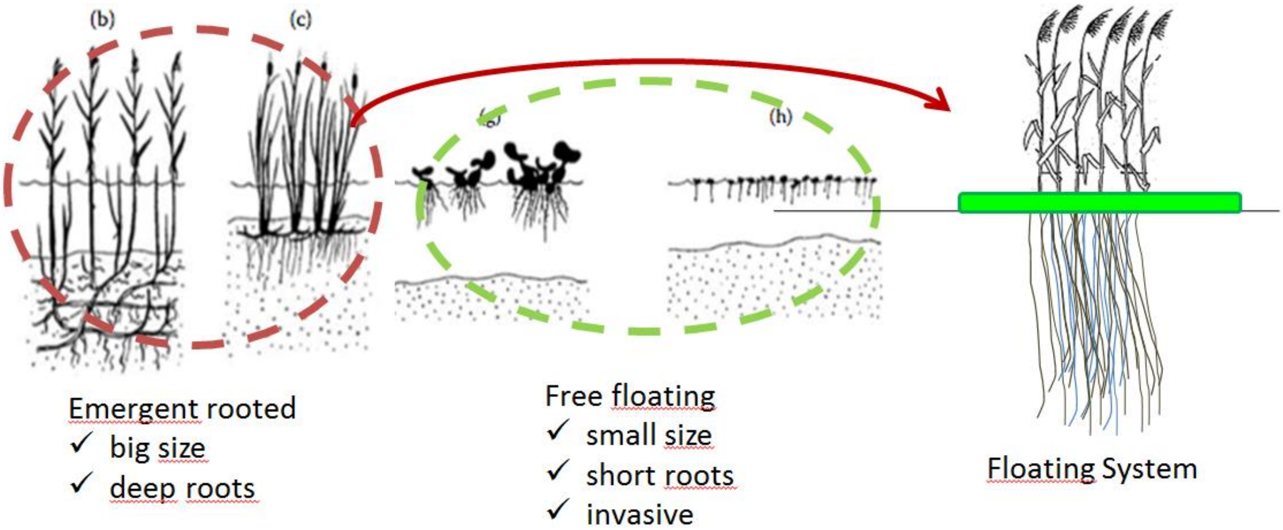

Figure 1: The concept of the floating system

Vegetated floating islands, stable or temporarily, are used in several environments with different purposes (Table 1). The floating mats shade the water column and create a quiescent environment that reduces algal growth and promotes settling of suspended solids and biofilms formation.

In this presentation a description of the potential given by the floating element TECH-IA to install floating barriers and islands in the urban environment is given, together with some examples of installation in Italy.

2 The TECH-IA floating mat

TECH-IA system is a proprietary technology of Padua University spin-off PAN Ltd. In 2006 the patent demand was presented at the Italian Patent Office (Tech-IA®). The multitasking floating system is indicated as support for herbaceous and arboreal plants. Its main use is within the field of natural depuration in water bodies.

Table 1. Examples of application of FTWs in the world

Location	Reference	Floating mats	Plant species	Wastewater
Belgium	Van Acker *et al.* (2005)	PE-net+PE-foam with coconut fibres	*Carex spp., Phragmites australis, Shoenoplectus latifolia, Typha spp., iris pseudacorus*	Combined sewer overflow
USA, Las Vegas	Boutwell (2002)	HDPE-shipping pallets, stainless steel and coconut fibres	*Shoenoplectus spp., Typha spp*	Lake water
USA, Georgia	Hubbard *et al.* (2004)	PVC pipes and fibrous material	*Panicum hemitomon, Typha latifolia, Juncus effusus*	Swine lagoon
India	Billore and Prashant (2008)	Bamboo, PVC fibres, galvanized iron wire and nylon coconut fibres	*Phragmites karka*	Lake water
New Zealand	Tanner and Headley (2011)	polyester fibre injected with patches of polystyrene foam (BioHavenTM, Floating Islands)	*Carex dispacia, Carex virgata, Cyperus ustilatus, Eleocharis acutis, Juncus edgarae, Schoenoplectus tabernaemontani*	Stormwater
Canada	Smith and Kalin (2000)	Timber, plastic snow fences, fishing net, Styrofoam, plywood panels and Sphagnum spp. Moss on a burlap liner	*Typha spp.*	Acid mine drainage
Uganda	Kyambadde *et al.* (2005)		*Cyperus papyrus, Miscanthidium violaceum*	Stabilization pond
U.K., England	Revitt *et al.* (2001)	Plastic geotextile lattice	*Phragmites australis*	Stormwater
Belgium	Van de Moortel (2011)	Plastic pipes filled with foam and wire netting	*Carex acutiformis, Iris pseudacorus, Juncus effusus*	Combined sewer overflow
NewSouth Wales, Australia	Hart *et al.* (2003)		*Chrysopogon zizanioides*	Septic tank effluents
France	Ladislas *et al.* (2010)	Polyethylene plot with Puzzolana, polystyrene float.	*Juncus effuses, Carex riparia*	Stormwater
USA	Stewart et al., 2008	BioHaven® floating islands	Microbes only	Agricultural and municipal wastewater

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The single self-floating element of Tech-IA® is made of recyclable material (ethylenvinil acetate, EVA), and is of rectangular shape (45*90 cm) with eight windows each of them with grids that allows to sustain the plants (Figure 2). It weighs 1730 g and may support a weight of 20 kg. Two connected elements result in one square meter of raft. The frame has six holes, and the single elements can be easily linked to each other and anchored to the riversides. The elements can be easily installed in different designs to fit the shape of the water body and intercept the pollutant flow.

The structure was created to be a support for non floating plants in phytodepuration, but it can be used in several other sectors. It could become vegetated island for naturalistic and wildlife purposes, floating vegetated or no-vegetated barriers used for delimitation or signal. But also decorative island in natural, artificial, private or public water body, support for plants that grows in hydroponic system, creation of buoyant platforms and as support for fish farming environments.

The technical features of this structure are a high mechanical resistance of the material associated with biological, chemical and climatic resistance, a closed cell structure that doesn't absorb water and easy installation and management. These structures are able to sustain aquatic plants, which are able to extend their roots in the water column, in calm or running waters, and perform the typical functions: physical filtering of the water flow and dissolved nutrients uptake.

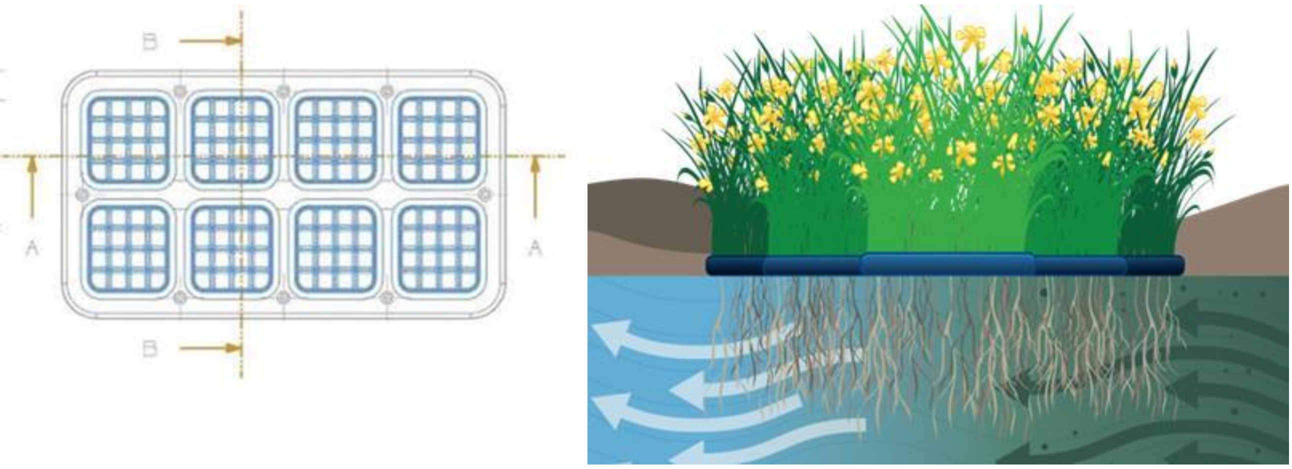

Figure 2: Tech-IA floating element and its working scheme

3 Experiences in Italy

In Italy the floating wetland system was applied in 2005 for the first time to treat water outflow from a fish farm. Since then, several experiments were carried out with the purpose to study the most suitable vegetation to be used and the performance of floating barriers for FTW purposes.

3.1 The vegetation

The vegetation fulfils multiple functions in wetland systems; the attention has to be drawn on aquatic plants with well-developed root system, with not too tall aerial parts to avoid the risk of reversal of the barrier do to wind gusts. If the barriers or islands are installed with aesthetic purposes it becomes interesting to consider the flower characteristics (colour, size, duration of inflorescence), the phenology (with particular attention to time and duration of flowering), and other potentially interesting features, such as shape, colour and duration of leaves, perfume emissions etc.

The most interesting plants are:

Iris pseudacorus L. (Figure 3) is native in Europe. It is well known for its big yellow flowers that bloom in early spring, from May to June. It reproduces from rhizome, has leaves that branch from the base of the plant and are large up to 3 cm. Every year plants release new shoots from the rhizomes. It grows in mid or full sun close to water but also submerged till about 15 cm, within a wide range of pH-values, from acid to alkaline; it is very strong, can resist to flood and dry periods too. *Iris* is often used in constructed wetlands for its capacity of pollution removal and in FTWs too (Van de Moortel , 2011).

Figure 3: *Iris pseudacorus* L.

Iris laevigata Fisch. This species originates from East Asia and is cultivated especially in Japan. Its name is due to its petals that are rotund, short and vertical. This *Iris* needs humid soil all over the year and does not tolerate dryness; it prefers acid or neutral pH and loves to leave in water till 15 cm depth. It reaches more than 90 cm in height and can be up to 30 cm in width, depending in which climate it grows, even if it prefers temperate one. Flowers are about 7 to 10 cm long, and bloom in summer; they can be white, blue or red-purple.

Canna indica L. Cultivated as ornamental plant, it can reach the height between 150 and 250 cm. The leaves and the flowers are very decorative and different varieties that bloom during summer can have different colours with lots of shades. This species loves sun but can tolerate shadow too. In winter above ground vegetation disappears but rhizomes stay alive below ground, to grow in spring again. It is sensitive to cold winters.

Figure 4: *Canna indica* L.

Juncus effusus 'spiralis' L. This aquatic macrophyte, typical of wetlands, has smooth, lucid and bright green stem that twist from the base of the plant. Its green-brown inflorescence appears in summer. It can be up to 90 cm high and 60 cm wide. It grows in humid or swampy soil, and also in shallow water, it is excellent for aquatic garden. This species has been widely used in FTWs (Van de Moortel, 2011; Hubbard et al., 2004).

Mentha aquatica L. (Figure 5) belongs to the family of *Labiatae,* which includes many of species often used in perfumery and medicine thanks to their production of essential oil composed mainly of menthol. Flowers of this herbaceous species are pink-purple and appear in summer; it can reach 80 cm in height, even if its aerial part is creeping. Its woody rhizomes produce aboveground creeping stolons. It is typical of wetlands, such as riverside, on bogs or swamps. It thrives in shadow and humid environments, from the sea to the mountains.

Pontederia cordata L. (Figure 6) belongs to *Pontederiaceae* and is native from North America. Its leaves are lucid and heart shaped, and its big decorative flowers can be white, blue, pink or lavender and bloom in summer. This plant is often used as water filter (McConnel et al., 1990). Normally these plants propagate by division of rhizomes in spring but they can also been seeded even if they need a period of dormancy with cold and humid conditions. To survive at cold temperatures is important that young plants originate from cultivars that were grown in cold climate (Kane et al, 1991). It can grow in full sun or middle shadow in humid soil or in water till 25 cm depth. It reaches 60-75 cm in height (Speichert and Speichert, 2004).

In addition to this list the well-known, and widely used *Typha latifolia* L., and *Phragmites australis* (Cav.) Trin. ex Steud have been used in Italian installations of Tech-IA (De Stefani et al., 2010; 2011; 2012; Mietto et al., 2013).

Figure 5: *Mentha aquatica* L.

Figure 6: *Pontederia cordata* L.

3.2 Installations

Different installations have been realised in Italy, the prevalence of them in peri-urban basins downstream of wastewater treatment plants with the main goal of tertiary treatment. In some cases Tech-IA barriers have been directly installed in streams, channels, and in accumulation basins. Projects have been also presented to Municipalities with the purpose to enhance the aesthetic value of channels in urban environment.

The designs of the systems were always different site to site (Figure 7), according to local needs and conditions. The installation was easily managed, as well as the maintenance operations. The vegetation was able to colonise the mats and develop root systems reaching 40-50 cm of depth at the end of the first growing season. The performance in ameliorating water quality has been different in relation to the pollutant type, the concentrations upstream the barriers, and the residence time. Reduction of pollutants reaching up to 70% for total nitrogen, 49% for ammonia-N and 67% for nitrate, 30% for phosphorus forms, and 60% for COD have been measured (De Stefani et al., 2012).

Tech-IA floating installations also contributed new sites for wildlife, since many nests of aquatic birds were found in the vegetation and fishes used the root system as refuge and sites to attach their eggs.

4 Conclusions and perspectives

Tech-IA floating system proved to be a very simple and flexible tool to build vegetated barriers or islands in different types of water bodies. The installation is very easy and the design can also be modified during the time according to new needs and perspectives. The adequate choice of vegetation can enhance the value of the installation, offering an interesting aesthetic value. Multiple possibilities of use can be considered in urban environments: in internal channels, in lakes or pools inside parks and green areas, in basins collecting and treating runoff water, as FTW downstream of wastewater treatment plants and in many other sites where the objective is the amelioration of water together with the enhancement of the environmental quality.

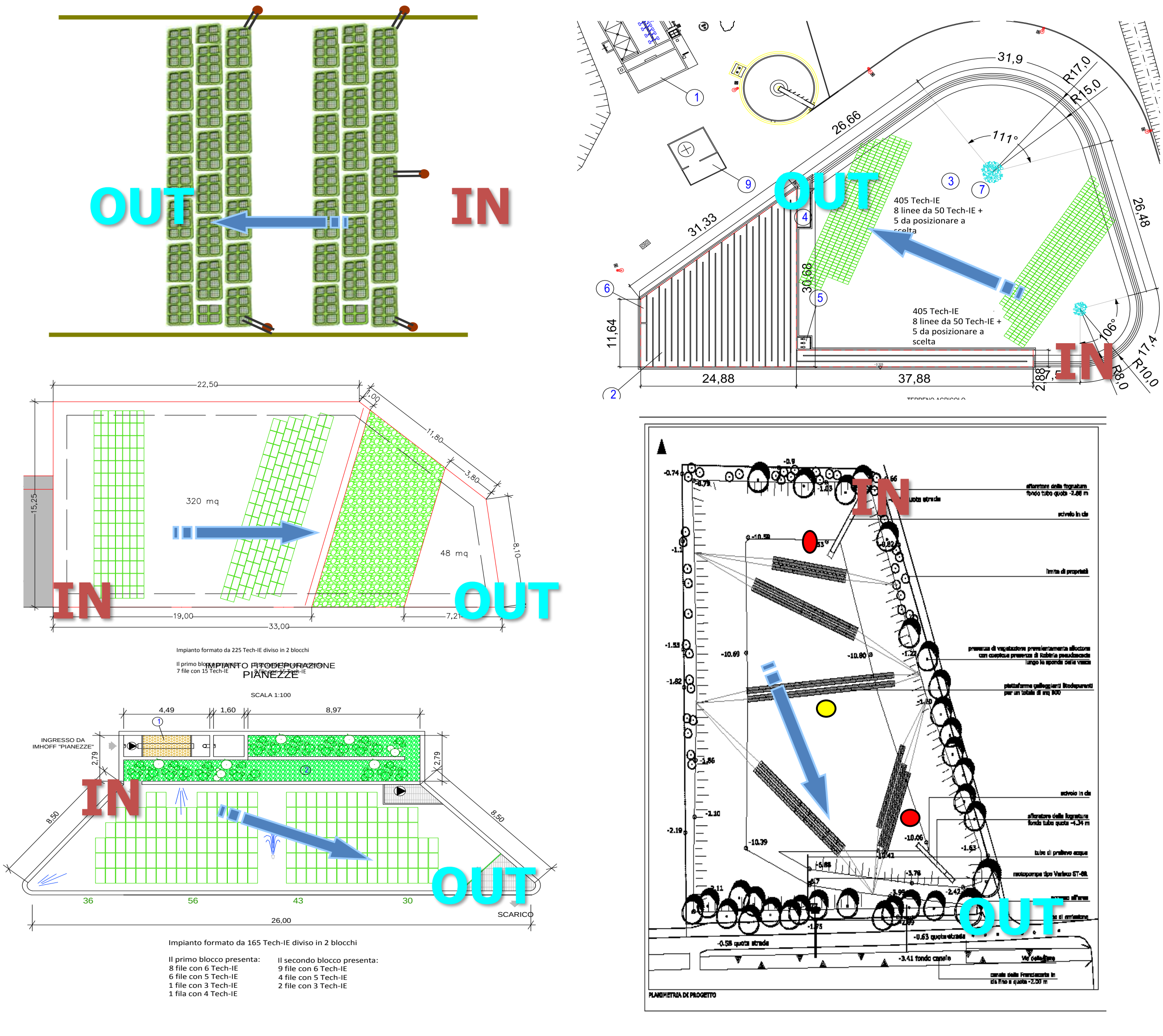

Figure 7: Some examples of Tech-IA installation schemes in Italy

5 Bibliography and sources

Billore S.K. and Prashant S.J.K.. Restoration and conservation of stagnant water bodies by gravel-bed treatment wetlands and artificial floating reed bed in tropical India. *Proc. of 11th International Conference on Wetland Systems for Water Pollution Control*, 2008, Indore, India: 408–413

Boutwell, J.E. Water quality and plant growth evaluations of the floating islands in Las Vegas Bay, Lake Mead, Nevada, 2002. U.S, Department of the Interior, Bureau of Reclamation, Denver, Colorado, pp. 24.

De Stefani G., Mietto A., Salvato M., Borin M. Performance of a combined wetland (h-SSW and FTW) in treating municipal wastewater in Veneto Region (Italy). *Proc. 13th International Conference on Wetland Systems for Water Pollution Control*, 2012, Perth, Australia

De Stefani G., Tocchetto D. and Borin M. Performance of a floating system as tertiary treatment for urban wastewater. *Proc. of 12th IWA Int. Conference on Wetland systems for water pollution control*, 2012, Venice, Italy, 287-288

De Stefani G., Tocchetto D., Salvato M. and Borin M. Performance of a floating treatment wetland for in-stream water amelioration in NE Italy. *Hydrobiologia*, 2011, 674, 1, 157-167

Hart B., Cody, R., Truong P. Hydroponic vetiver treatment of post septic tank effluent. *Proc. Third International Conference on Vetiver*, 2003, Guangzhou, China.

Hubbard R.K., Gascho G.J. & Newton G.L. Use of floating vegetation to remove nutrients from swine lagoon wastewater. *Transactions of the ASAE*, 2004, 47:1963-1972.

Kyambadde J., Kansiime F. and Dalhammar G. Nitrogen and phosphorus removal in substrate-free pilot constructed wetland with horizontal surface flow in Uganda. *Water, Air, and Soil Pollution*, 2005, 165: 37–59.

Ladislas S., Garente C., Chazarene F., Andrea Y. and Brisson J. Performances of floating treatment wetlands to remove cadmium, nickel and zinc from urban stormwater runoff. Proc. *12th International conference on wetland systems for water pollution control*, 2010, Venice, Italy.

McConnel D.B., Kane M.E. and Shiralipour A. Growth of pickerelweed in municipal solid waste compost and yard trash compost. *Proc. Fla. State Hort. Soc*., 2010, 103: 165-167.

Mietto A., Borin M., Salvato M., Ronco P., Tadiello N. TECH-IA floating system introduced in urban wastewater treatment plants in Veneto Region – Italy. *Water Sci. and Techn.*, 2013, 68.5, 1144-1150

Revitt D.M., Worrall P., Brewer D.. The integration of constructed wetlands into a treatment system for airport runoff. *Water Sci. and Techn*, 2001, 44: 469-476.

Smith M.P., Kalin M. Floating wetland vegetation covers for suspended solids removal. Treatment wetlands for water quality improvement. *Proceeding of Quebec 2000 Conference*, CH2MHILL, Canada.

Stewart, F.M., Mulholland, T., Cunningham, A.B., Kania, B.G., Osterlund, M.T. Floating islands as an alternative to constructed wetlands for treatment of excess nutrients from agricultural and municipal wastes - results of laboratory-scale tests. *Land Contamination & Reclamation*, 2008, 16: 25–33.

Tanner C.C., Headley T.R. Components of floating emergent macrophyte treatment wetlands influencing removal of stormwater pollutants. *Ecological engineering*, 2011, 37: 474-486.

Van Acker J, Buts L., Thoeye C., De Gueldre G. Floating plant beds: BAT for CSO treatment? *Book of abstracts from international symposium on wetland pollutant dynamics and control*, September 4-8, 2005, Ghent Belgium: 186-187.

Van de Moortel, A.M.K. Constructed floating wetlands for combined sewer overflow water treatment. PhD thesis, faculty of bioscience Engineering, 2011, Ghent University, Ghent, Belgium. 244 p.